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HOMEMADE SILOS.

By ~~HELMER RABALA~~ A. K. RISSEK, and K. E. PARKS, of the Dairy Division.

INTRODUCTION.

Green corn was first preserved for winter feeding in the United States by Prof. Manly Miles, of Lansing, Mich., in 1875.¹ He used shallow pits 8 inches deep into which he heaped the cut corn and then covered it with earth. Francis Morris, of Maryland, is said to have built a silo in 1876, and J. M. Bailey, of Massachusetts, one in 1879.

Silo construction has undergone a great change since the first ones were built. All the early silos were built in the ground, while the modern silos are constructed almost entirely above the ground. Besides this, the first silos were comparatively shallow structures, which resulted in a large amount of spoiled silage on account of lack of sufficient pressure.

Since about the year 1880 silos have increased rapidly in number in the United States, until now they are extensively used, especially in those regions devoted to the dairy industry. So useful have silos become that many farmers consider them indispensable. The demand for literature on silos has likewise increased. This bulletin has been prepared for the purpose of partly meeting this demand by furnishing such information as will enable the farmer to construct his own silo at a reasonable cost.

GENERAL CONSIDERATIONS.

ADAPTABILITY OF THE SILO.

The silo is adapted to all parts of the United States where corn or the sorghums can be successfully grown. Its use at present is confined principally to farms where cattle are kept, although silage is a good and cheap feed for both sheep and horses.² Dairy farmers especially

¹ Country Gentleman, October 5, 1876, page 628.

² See Farmers' Bulletin 578, "The Making and Feeding of Silage."

NOTE.—This bulletin gives detailed instructions for building three types of silos, namely, concrete, stave, and the modified Wisconsin silo. The part relating to the stave silo is a revision of Bureau of Animal Industry Circular 136, by B. H. Rawl and J. A. Conover.

have appreciated the value of silage as a milk producer. To make the silo a profitable investment, however, a man should have at least 10 cows or the equivalent of this number in other stock. With a number fewer than this the relative cost of the silo and the silo-filling machinery becomes excessive; besides it is not usually feasible to build a silo small enough to accomodate fewer than 10 head.

KIND OF SILO TO BUILD.

After a person has decided to put up a silo, the next question is, What kind of a silo shall it be? Several factors will enter into this consideration, chief among which are cost and durability. On account of lack of space only three of the most common and approved types of silos will be discussed in detail here, namely, the concrete, the stave, and the modified Wisconsin silos. The concrete silo, as the name implies, is built entirely of concrete; the stave silo is built of long 2 by 4 or 2 by 6 material, set vertically like the staves of a wooden tank; the modified Wisconsin silo is built of three-eighths or one-half inch boards nailed laterally on the inside of studding placed in the form of a circle. All these will preserve silage equally well.

THE THREE COMMON TYPES.

Concrete silos.—The concrete silo has the advantage of the other two in permanency and stability. A well-constructed concrete silo will last indefinitely; there is no danger of its blowing or burning down, rotting out, or being attacked by vermin. For the man who wants a silo for a considerable number of years and who can obtain materials for concrete at a reasonable cost the concrete silo is advisable. The necessary repairs are reduced to a minimum, the first expense being practically the only expense. Little attention is required to keep the structure in good condition. The chief objection to the concrete silo is its cost. It is more expensive, as a rule, than either of the other two types.

The stave silo.—The stave or tub silos have become very popular in late years because of the cheapness, ease, and quickness with which they are constructed. Generally speaking, the stave silo excels in these three particulars, although there may be sections of the country where sand and gravel may be obtained at a nominal cost and where the price of lumber is excessive. Under such conditions the concrete type may be the cheaper. Manufacturing firms have made a specialty of stave silos and have pushed their sale; as a consequence such silos are more numerous in the United States to-day than any other type.

Stave silos, however, are temporary structures, since they last only from 5 to 15 years, depending upon the kind and quality of lumber used, the care and the construction of the silo, and the climate. They are more liable to blow down, fall down, or otherwise get out of repair than either of the other types of silos.

The modified Wisconsin silo.—It sometimes happens in certain sections that it is inconvenient to secure hoops or lugs for a stave silo. Under such conditions the modified Wisconsin type is to be recommended. The modified Wisconsin silo is more substantial than the stave silo; that is, it is not so liable to be blown down or to get out of repair through drying. It does not need so much attention. In case some parts of the walls rot out they can be more easily repaired than those of a stave silo. Another advantage of this type over the stave silo is that carpenters as a rule take hold of the work of construction more readily. They seem to have a better idea as to just how to go about putting up this kind of a structure.

There are two serious objections to the modified Wisconsin silo. One is that a silo less than 14 feet in diameter is very hard to build, owing to the difficulty in bending the sheathing. Another is the unfinished appearance of the structure.

Cost of construction.—The cost of the above-mentioned silos will depend so much upon their size and on the price of material and labor that no definite amounts can be assigned which would be applicable to all conditions. Recent data on the cost of homemade silos collected by the Dairy Division from all parts of the country show the following relative cost of the three types:

Cost of silos.

Type of silo.	Number of silos.	Average capacity.	Average cost.	Average cost per ton capacity.
		<i>Tons.</i>		
Concrete:				
100 tons or less.....	71	71	\$220.47	\$3.10
101 to 200 tons.....	50	135	348.68	2.59
More than 200 tons.....	23	219	446.42	2.04
Total concrete.....	144	117	301.08	2.58
Modified Wisconsin.....	8	116	186.52	1.61
Stave:				
100 tons or less.....	25	63	118.40	1.87
Over 100 tons.....	16	129	187.46	1.45
Total stave.....	41	89	145.35	1.63

Plans for the above silos were furnished by the Dairy Division, and frequently a representative of the division assisted in laying out the foundation and getting the building underway. The figures given will serve to show in a general way the cost of the three types of silos.

OTHER TYPES OF SILOS.

Other less common kinds of silos are the Gurler, the Iowa, and brick and stone silos.

The Gurler.—The construction of this silo is similar to that of the Wisconsin, the main difference being that the inner lining of wood

in the Wisconsin type is replaced by a coating of lath and cement plaster. Its principal fault is that owing to lack of rigidity the concrete lining may crack and admit air.

The Iowa.—This silo is constructed of hollow tile blocks reinforced with steel. The air space provides some protection against the freezing of the silage. It is apparently a durable and substantial structure. This silo has been in use only a few years, so it would be difficult to say at this time just how it compares with the other types. It is probable that if good tiles adapted for the purpose can be secured at a reasonable price this silo will come into more general use.

Brick and stone silos.—These silos have been used to some extent, and with much satisfaction when properly constructed. They are, however, expensive and have nothing to recommend them as compared with concrete. The tendency seems to be away from rather than toward brick and stone silos.

ESSENTIAL FEATURES IN THE CONSTRUCTION OF SILOS.

There are some features which are essential to the construction of all silos and without which silage will not be kept in perfect condition.

1. The walls should be air-tight. Since the keeping of silage depends upon the exclusion of air it is imperative that the walls of the silo be built in such a way as to keep out the air. The lumber should be well matched, and that containing large knots should be rejected. In concrete silos a wash on the inside with cement or with raw coal tar thinned with gasoline is effective in making the walls impervious to air. Care should be taken that the doors fit closely into their frames.

2. The walls should be smooth and plumb so that the silage will not adhere to them in settling and thus cause air spaces in the outer edge of the silage. Furthermore, the walls should be capable of standing considerable lateral strain without cracking or bulging. This is one reason why rectangular silos are unsuccessful.

3. The silo must be deep enough so that the pressure from above will thoroughly pack the silage and force out the air. The greater the pressure the less air is left in the silo and the less will be the loss of food materials by fermentation.

4. The only form of silo to be recommended is one which is round. This form is the cheapest, capacity considered, and the walls are more rigid than those of the rectangular or octagonal forms. This results in more perfect preservation of the silage.

THE LOCATION OF THE SILO.

The silo should be placed outside rather than inside the barn. As a silo ordinarily does not need the protection of a barn, it is not economical to use barn space for this purpose. An exception to this rule

may be made in the case of the round barn. A silo in the middle of a round barn serves to support the superstructure as well as to place the silage in a position for convenient feeding. A silo so placed, however, is liable to be very inconvenient to fill. The most popular location is not more than a few feet from the barn and opening into a separate feeding room. The door of the barn can then be closed and the silage odors kept out of the stable at milking time.

The silo should not be built in the ground so deeply as to make it necessary to lift the silage more than 5 feet in getting it out from the bottom. In other words, the bottom should not be more than 5 feet below the lowest door.

THE SIZE AND CAPACITY OF THE SILO.

Diameter.—The diameter of the silo will depend upon the amount of silage to be fed daily. The silage should be removed from the top at the rate of $1\frac{1}{2}$ to 3 inches per day, depending upon climatic conditions. The warmer the weather the more silage must be removed from the surface daily in order to prevent spoiling. For the winter-feeding season it is safer to figure upon removing 2 inches daily rather than a smaller amount. A common error in building is to make the diameter too large for the size of the herd. • The weight of a cubic foot of silage varies according to the pressure to which it is subjected, but in a silo 30 feet deep it will average about 40 pounds. So, by knowing the amount of silage to be fed daily, it is possible to estimate what the diameter of the silo should be to permit the removal of a certain number of inches in depth each day. The following table will show the proper diameter of the silo for herds of different sizes to be fed different amounts for winter feeding, when 2 inches of silage are removed daily:

Relation of size of herd to diameter of silo for winter feeding (on basis of 40 pounds of silage per cubic foot).

Inside diameter of silo.	Quantity of silage in depth of 2 inches	Number of animals that may be fed allowing—			
		40 pounds per head.	30 pounds per head.	20 pounds per head.	15 pounds per head.
<i>Feet.</i>	<i>Pounds.</i>				
10	524	13	17	26	35
11	634	16	21	31	42
12	754	19	25	37	50
13	885	22	29	44	59
14	1,026	25	34	51	68
15	1,178	29	39	59	78
16	1,340	33	44	67	89
17	1,513	38	50	75	101
18	1,696	42	56	85	113
20	2,094	52	70	104	139

A 900-pound cow will ordinarily consume 30 pounds of silage a day; a 1,200-pound cow about 40 pounds. Yearlings will eat about one-half as much as mature animals; fattening cattle, 25 to 35 pounds for each 1,000 pounds live weight. A sheep will take about one-eighth as much as a cow. Horses should be limited to 15 or 20 pounds daily.

The practice of using silage to supplement pastures during the summer droughts and in the early fall, instead of soiling crops, is becoming more general and it should be encouraged. For such feeding the daily ration per cow may be as low as 10 pounds, depending upon the amount and quality of pasture or other succulent feeds available. For the same herd the silo for summer feeding should be of smaller diameter than the one used for winter feeding, since 3 inches instead of 2 are to be removed daily. In order to provide for this summer feeding an additional silo of smaller diameter should be constructed.

The following table shows the relation between the size of the herd and the diameter of the silo when 3 inches of silage are removed daily:

Relation of size of herd to diameter of silo for summer feeding (on basis of 40 pounds of silage per cubic foot).

Inside diameter of silo.	Quantity of silage in depth of 3 inches.	Number of animals that may be fed allowing—			
		40 pounds per head.	30 pounds per head.	20 pounds per head.	15 pounds per head.
<i>Feet.</i>	<i>Pounds.</i>				
10	785	19	26	39	52
11	950	23	31	47	63
12	1,131	28	37	56	75
13	1,327	33	44	66	88
14	1,539	38	51	77	102
15	1,767	44	59	88	118
16	2,011	50	67	100	134

Depth.—After the diameter of the silo has been decided upon, the next consideration is the number of tons of silage that will be required, and this is governed by the length of the silage-feeding season. When the number of tons and the diameter have been fixed upon, a reference to the table below indicates what the depth of the silage should be. For example, if the diameter is 14 feet and the capacity 100 tons, the depth of silage after settling for two days should be 32 feet. An allowance of 4 to 6 feet must be made for settling in a silo 30 or more feet deep, so that the height of the silo in this instance from the floor to the plate should be 36 to 38 feet.

Depth of silage (after settling) for a given capacity of silo with a given diameter.¹

Depth of silage (after settling).	Capacity of silo having an inside diameter of—									
	10 feet.	11 feet.	12 feet.	13 feet.	14 feet.	15 feet.	16 feet.	17 feet.	18 feet.	20 feet.
<i>Feet.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>
24	34									
26	38	46	55							
28	42	51	61	71	83					
30	47	56	67	79	91	105				
32		62	74	86	100	115	131			
34			80	94	109	126	143	161		
36			87	102	119	136	155	175	196	
38				110	128	147	167	189	212	261
40					138	158	180	203	228	281
42						170	193	218	245	302
44							207	234	262	323
46								250	280	345
48										368

¹ These figures were taken in part from King's *Physics of Agriculture*, page 424.

In general, the depth of the silo should not be less than twice nor more than three times the diameter. The greater the depth the better the silage, on account of the pressure from above. If less than 24 feet in height the quality of silage will not be the best. A very great height, however, is to be avoided on account of the excessive amount of power required to elevate the cut corn into the silo.

FOUNDATION.

The foundation of the silo should receive special consideration, since a large proportion of the silage as well as the weight of the walls must be supported by the foundation. It has always been assumed that the foundation supports only the walls of the silo, but recent investigations have shown this idea to be erroneous. The foundation should have its base on firm soil, and it should extend below frost line. In the North this will require that it be placed 4 feet or more below the surface of the ground; in the South 2 feet will ordinarily be sufficient. The dimensions of the foundation wall will depend primarily upon the character of the soil in which it is located and the size of the silo. The base of the foundation must be wider in loose soils than in clay soils, so as to prevent the walls from cracking and settling out of shape. The width of the base will vary from 10 to 30 inches, depending upon the conditions mentioned.

FLOOR.

If the earth in the bottom of the silo is firm and comparatively dry, no provision need be made for drainage, and a floor is unnecessary. Still a concrete floor will make the silo easier to clean and make it impossible for rats to burrow underneath the foundation wall and gain access to the silage. If, however, the earth in the bottom of

the silo is inclined to be seepy, a tile drain should be laid in it and a concrete floor laid above the tile. The tiling should open into the floor in the center, and the floor should be made to drain to it. The tiling should extend beyond the silo wall and have its outlet lower than the floor. The entrance of the tile drain should be stopped with a loose wooden plug when the silo is about to be filled and should be opened when the silo is empty. The drain will carry off the water which tends to seep in, as well as any rain water that may collect on the floor in case the silo has no roof.

DOORS.

The doorways have always been a source of weakness in silo construction. When poorly made they have sometimes let the silo crack open and spread. Ample provision should therefore be made for reinforcing the structure in the region of the doors. The door should form an air-tight joint with its frame; tar paper is oftentimes useful in this connection. The door should be flush with the inner wall of the silo so that air pockets will not form as the silage settles.

Doors should be of such size as to permit the ready entrance of a man, and they should be close enough together so that the silage will not have to be lifted any considerable height when it is being removed. The usual size is about 20 inches wide and 30 inches high, and the space between the doors $2\frac{1}{2}$ to 3 feet. The lowest door should not be more than 5 feet above the bottom of the silo, and less than this is desirable. The table below will assist the builder in determining the number and spacing of the doors:

Number and spacing of doors in silos of different heights.

Height of silo above foundation.	Number of doors.	Height of door.	Space between doors.	Space below first door, to foundation or surface of ground.	Space above last door.
<i>Feet.</i>		<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
24	4	$2\frac{1}{2}$	$3\frac{1}{2}$	1	$3\frac{1}{2}$
26	5	$2\frac{1}{2}$	$2\frac{1}{2}$	1	$2\frac{1}{2}$
28	5	$2\frac{1}{2}$	3	1	$2\frac{1}{2}$
30	6	$2\frac{1}{2}$	$2\frac{1}{2}$	1	$1\frac{1}{2}$
32	6	$2\frac{1}{2}$	$2\frac{1}{2}$	1	$2\frac{1}{2}$
34	6	$2\frac{1}{2}$	3	1	3
36	7	$2\frac{1}{2}$	$2\frac{1}{2}$	1	$2\frac{1}{2}$
38	7	$2\frac{1}{2}$	$2\frac{1}{2}$	1	3
40	8	$2\frac{1}{2}$	$2\frac{1}{2}$	1	$1\frac{1}{2}$
42	8	$2\frac{1}{2}$	$2\frac{1}{2}$	1	$3\frac{1}{2}$
44	8	$2\frac{1}{2}$	3	1	2
46	9	$2\frac{1}{2}$	$2\frac{1}{2}$	1	$2\frac{1}{2}$
48	9	$2\frac{1}{2}$	$2\frac{1}{2}$	1	$2\frac{1}{2}$

The continuous door.—Many silos are now built with continuous doors, obstructed only by the hoops or bars extending from side to side which are necessary to prevent the door frames from spreading.

This kind of door is more convenient for the removal of silage, but it is harder to construct properly.

ROOF.

While a roof is not essential to the keeping of silage, it is advisable for several reasons to equip the silo with a roof. A roof adds to the appearance, life, and stability of the silo; it retards freezing; it keeps out rain and snow, making the work of removing the silage more agreeable; it will also prevent the silo from becoming a neighborhood feeding ground for pigeons. There should be a door in the roof large enough to admit the carrier or blower from the cutter. A simple trapdoor will answer the purpose, but a dormer window with glass is preferable, as this will admit light and so make the use of a lantern unnecessary when the silage is being removed.

CHUTE AND LADDER.

A chute should be built over the doors to prevent scattering of the silage when thrown down. This will make it possible to catch all the silage in a truck.

A ladder should be attached to the silo at one side of the doors or on the chute. Sometimes the reinforcing rods of the continuous door can be used for a ladder.

THE CONCRETE SILO.

Concrete silos are of three kinds—those built of concrete blocks, those made with concrete staves, and those with a solid wall, or the monolithic type. The only advantage of the concrete block silo over the monolithic is the fact that the walls can be more easily built with an air space, which would tend to prevent freezing. It is probable, however, that the difference between the two walls in this respect is of no considerable importance. It has the disadvantage of being more difficult to construct and requiring more expert labor, and as a consequence it generally costs more to build. On account of the limited amount of space in this bulletin which can be devoted to silo construction, the solid-wall or monolithic type is the only one which will be described in detail.

FOUNDATION.

To lay off the foundation, drive a stake in the ground at the center of the proposed silo. One end of a straight 2 by 4 inch scantling, a little longer than is necessary to reach from the center of the silo to the outside of the foundation wall, should be nailed on top of the stake with a 40-penny spike. This spike then marks the exact center of the silo. From it measure off on the scantling the distance to the

outside of the foundation wall, and having nailed on a marker, as shown in figure 1, lay off the foundation.

Where the ground on which the silo is to be located is not level, the marker can be lengthened by holding a longer board against it (see fig. 2), and moving it up or down to keep it touching the ground while the scantling is held level. If the ground is very uneven it may be difficult to make the line continuous, in which case points can be marked every few inches and these joined afterwards.

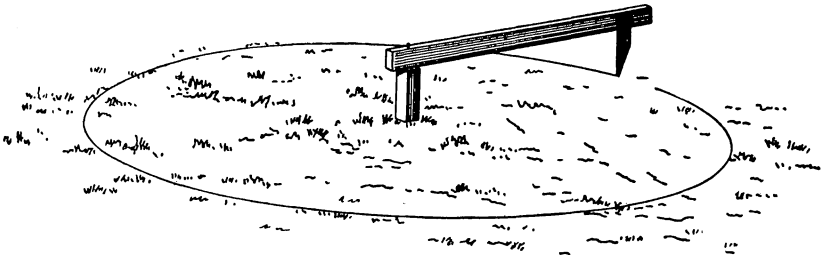


FIG. 1.—Laying off the foundation for a concrete silo.

The earth inside the circle must be excavated to firm ground below the frost line. A plumb line should be used in digging the pit so that the walls can be dug true to the mark. Generally the earth is firm enough to stand without danger of caving, and may serve as an outside form in building the foundation. (See fig. 3.)

Special footing.—If, however, the dirt caves in, the foundation can be built as shown in figure 4, in which case the pit must be dug large

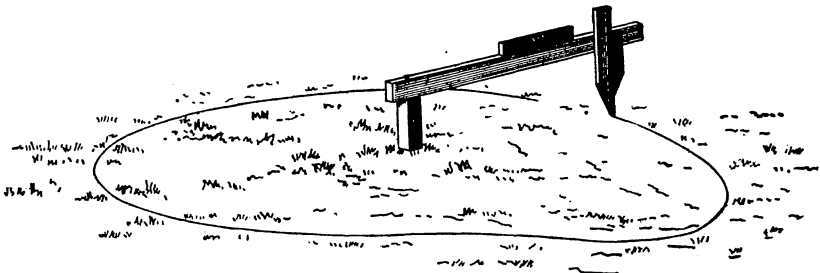


FIG. 2.—Laying off the foundation on sloping ground.

to give ample room for placing and removing the outside form. Aside from the matter of reinforcing, most of the failures of concrete structures have been due to insufficient and poor foundations, and special care should be taken to make this part of the silo secure. If the location is unfavorable for a good foundation and the silo is of very large capacity, it is well to put in a special footing in order to distribute the weight over a larger area of ground. (See fig. 4.)

MAIN WALL OF SILO.

The main wall of the silo is built 6 inches thick throughout, although for diameters of 12 feet and under a wall 5 inches thick has been found sufficient. No modification is made in the thickness of the wall for top and bottom, because the expense of adjusting the forms for such a variation more than equals the saving in cost of materials.

For building the wall two circular forms are needed, one inside the other, with a 6-inch space between them, into which the concrete is poured. The forms are built 3 feet high, and approximately 33 inches of wall can be built with each setting of the forms. The forms are so constructed that after each 33 inches of the wall has been placed the forms can be loosened, raised, and placed in position for another 33 inches of wall. In resetting, the forms are allowed to lap over the old wall about 3 inches, which greatly assists in getting them into proper position. (See fig. 5a).

FORMS.

Either wood or sheet metal may be used for forms, but where the metal can

be secured it is much to be preferred. It does not make so heavy a form as the wood, and the finished wall is smoother. Either 18, 20, or 22 gauge black or galvanized sheet iron 36 inches wide may be used. If, however, the diameter of the silo is to be 16 feet or more, it has been found more practical to have the sheets 30 inches wide, because in such cases one course around the silo at the reduced height of wall would be sufficient for an average day's work. The advantage of galvanized over black iron is that the form will last for a considerable time, and can be used for a number of silos of the same diameter during several seasons if properly cared for.

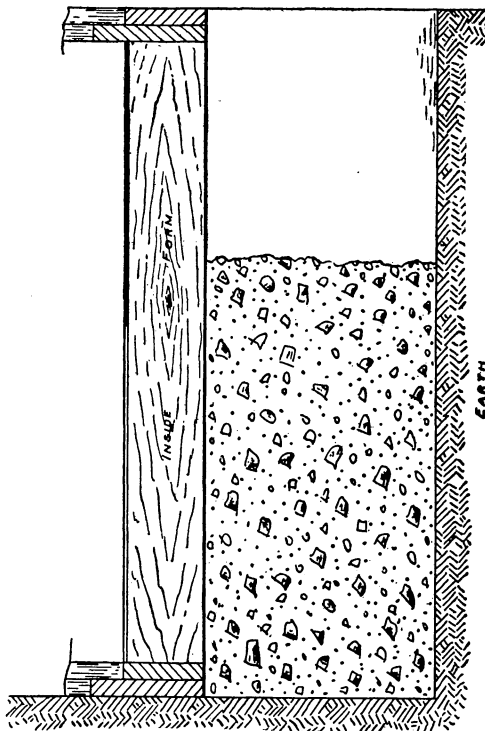


FIG. 3.—Method of constructing foundation in firm soil.

For each form it is necessary to build two supporting circles (See fig. 5*a*) to which the sheet iron or wood, as the case may be, is nailed.

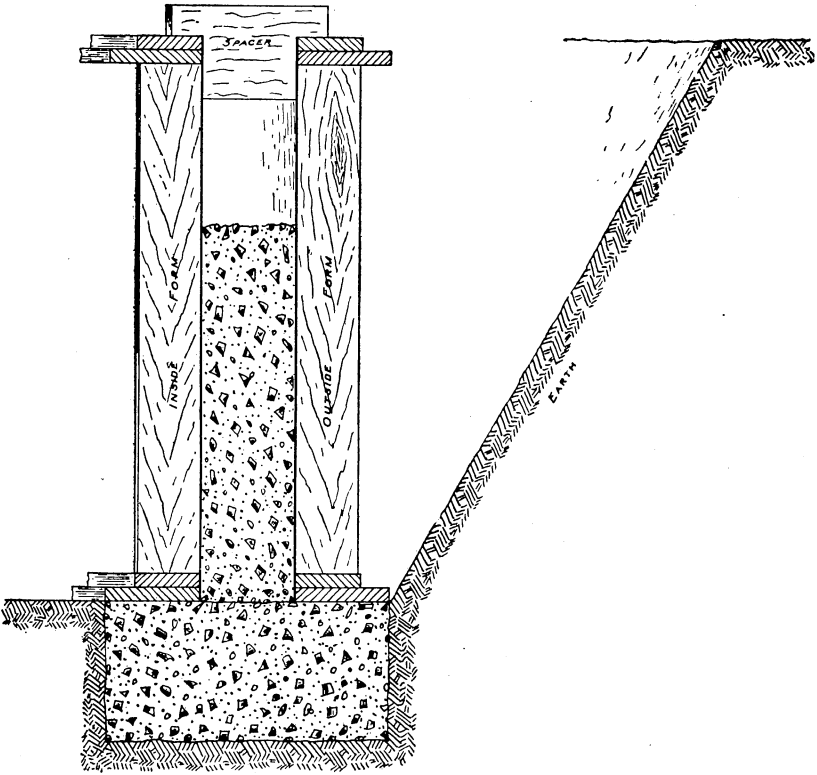


FIG. 4.—Method of constructing foundation in loose soil.

These circles are built out of 1 by 6 inch material, rough or dressed, of a length depending upon the diameter of the silo so that 16 pieces will exactly make the circumference. It is not an easy matter to compute these lengths of chords for the various diameters, so they are given below. In figure 6 the chord is the distance from A to B.

Table of chords.

Diameter of silo.	Chord measure- ment.	Diameter of silo.	Chord measure- ment.
	<i>Ft.</i> <i>In.</i>		<i>Ft.</i> <i>In.</i>
10 feet....	1 11 $\frac{1}{2}$	15 feet....	2 11
11 feet....	2 1 $\frac{1}{2}$	16 feet....	3 1 $\frac{1}{2}$
12 feet....	2 4	17 feet....	3 3 $\frac{1}{2}$
13 feet....	2 6 $\frac{1}{2}$	18 feet....	3 6 $\frac{1}{2}$
14 feet....	2 8 $\frac{1}{2}$		

LAYING OUT THE TEMPLATES FOR SHEET-IRON FORMS.

Figure 6 shows how to proceed to lay out the pieces to be used as templates, or patterns, by which to cut the pieces which when laid end

to end are to form the supporting circles for the inside and the outside forms when sheet iron is used. For this part of the work use the barn

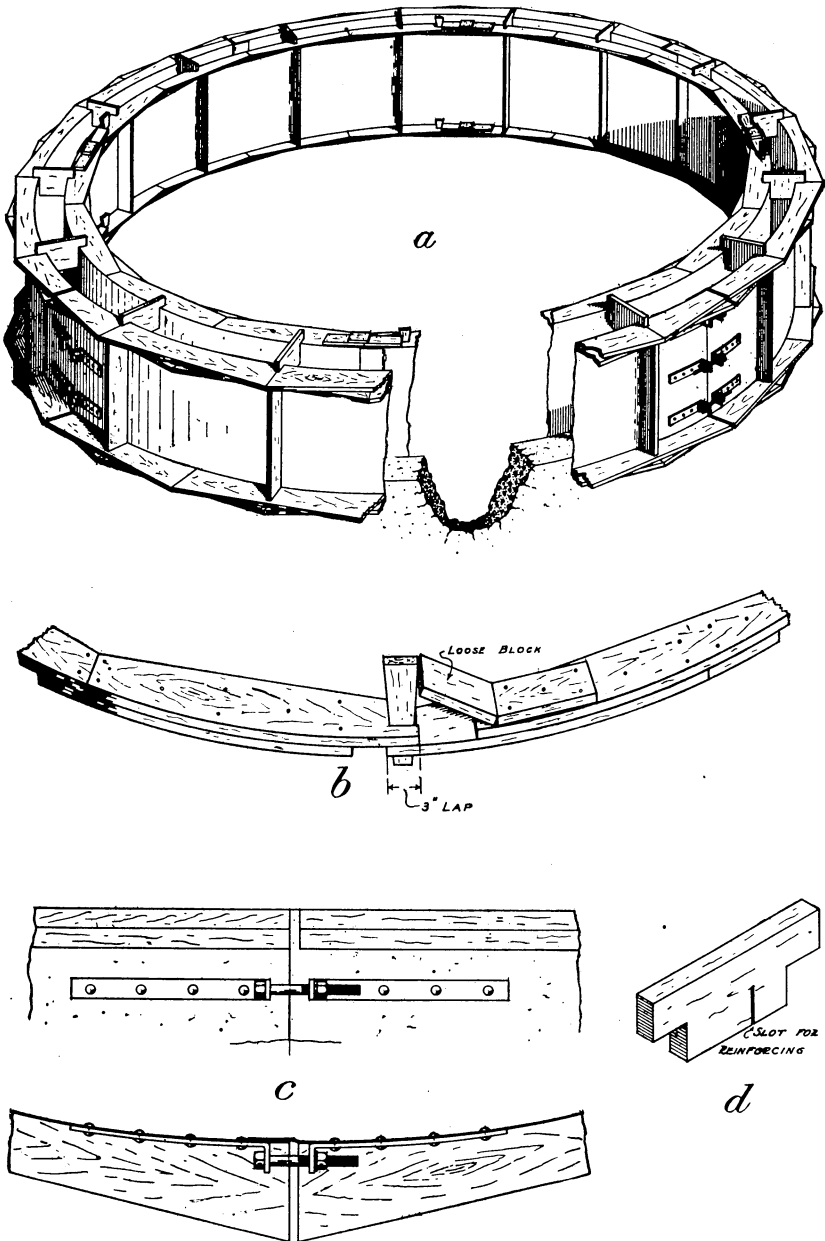


FIG. 5.—Silo form in position, and details of form.

floor or any clear space available. If there is no convenient place available, it will be advisable to build the concrete mixing board described later, and use that.

Select a straight piece of 1 by 3 inch board about a foot longer than half the diameter of the proposed silo, and with a 10-penny nail tack one end to the floor so that the slat will be free to swing about. From this nail as the center of the silo, measure off on the slat one-half the length of the inside diameter. Here drive a nail, and 6 inches beyond drive another nail until the points extend through far enough to scratch clear marks on the floor as the slat is swung around on the center O, as shown in figure 6. These circles represent the inside and outside faces of the wall. An arc equal to one-quarter of the circum-

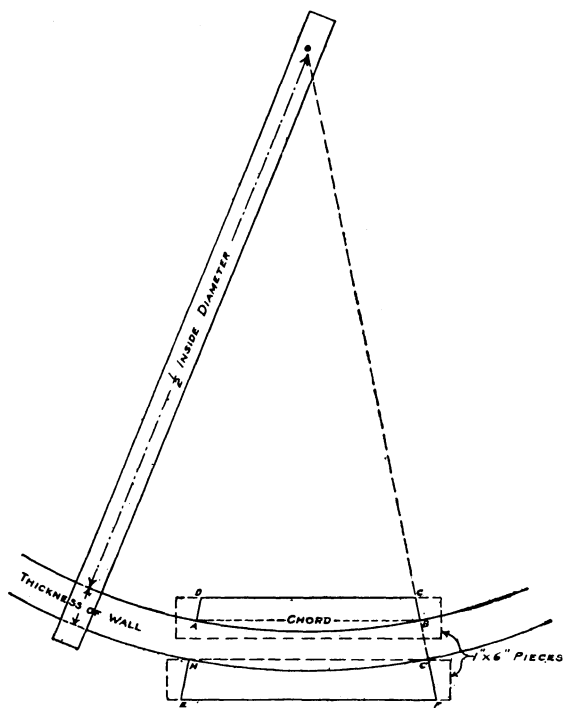


FIG. 6.—Method of laying out templates.

ference will be sufficient. From any point which has been determined to be A on the inside arc, measure off the length of the chord in figure 6 as given in the table of chords for the diameter of the proposed silo, and find point B. With a straightedge laid through the points A and O, and also through B and O, draw short lines on the floor from D to E and from C to F, respectively. On these lines measure inward 4 inches from points A and B, and locate points C and

D. Similarly measure outward from points H and G 6 inches to find the exact location of points E and F.

Next take two pieces of the 1 by 6 inch board and lay one of them on the arc with the inside edge flush with points C and D, as shown in figure 6. Lay the other on the outside arc with the outside edge flush with points E and F. With several small nails tack them to the floor. Next lay off the arcs again on these pieces, and with the straightedge re-mark lines DE and CF. The pieces are now ready to be taken up and sawed. The resulting patterns, or templates, will serve to mark out the 64 pieces necessary to build the two inside circles and the 64 pieces to build the two outside circles.

The curved pieces can be sawed by hand, but if there is a mill or shop convenient that is equipped with a band saw, it will hasten and generally cheapen the job to have it done there.

LAYING OUT THE TEMPLETS FOR WOODEN FORMS.

If the sheet iron for metal forms can not be obtained, or if for any other reason it becomes necessary to build wooden forms, then 1-inch flooring 3 inches wide and 3 feet long nailed on these supporting circles may take the place of the sheet iron. In working out the templets for wooden forms the nail used for marking off the inside circumference is driven 1 inch nearer the center to allow for the thickness of the flooring which is nailed on the circles instead of the sheet iron.

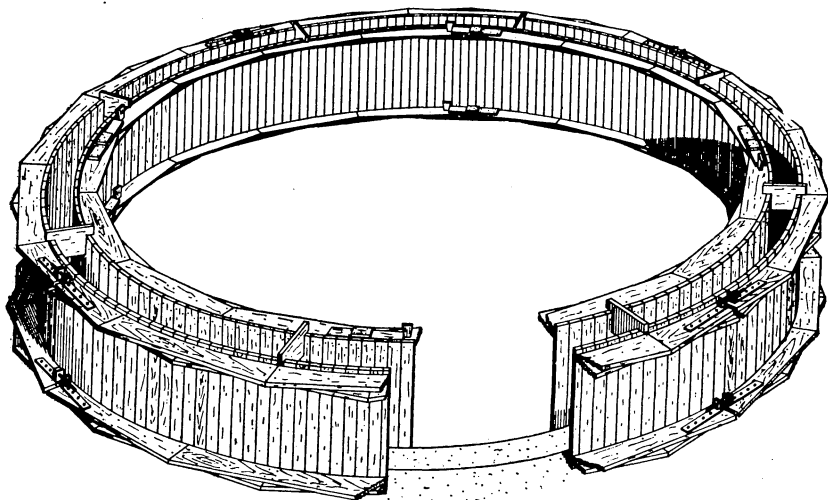


FIG. 7.—A wooden form for a concrete silo.

In other words, the inner circle is described 1 inch nearer the center and the outer circle 1 inch farther away from the center in order to allow for the thickness of the flooring. As shown in figure 7, the circles are raised one above the other, 26 inches apart, and the flooring is nailed on vertically with 8-penny nails. Before the flooring is nailed on it should be thoroughly soaked in water to prevent buckling later. Lugs are used similar to those used for sheet-iron forms. (See fig. 7.) Instead of riveting these lugs on the side, they are fastened on top of the circles with screws.

When these wooden forms are used, it must be remembered that they are heavy when soaked with water, and the scaffold must be built stronger accordingly.

BUILDING THE CIRCLES.

As shown in figure 7, each of the supporting circles is built two-ply, that is, the pieces are lapped so as to break joints. After cutting four or five pieces, lay them out on the circle, so as to make sure they fit the curve. Before starting to nail the pieces together, mark out the whole circumference on the floor or on a level piece of ground with the slat as shown in figure 6, and build the circles accurately by laying the pieces flush with the mark. It is important that the circles be well nailed with 8-penny nails driven through and clinched. While the circles are being built, approximate points of division into quarter circles can be marked, and those pieces nailed sparingly until after the circle is completed. It is generally safer to build the circles complete and then divide into quarter sections rather than to build each quarter separately. This division into parts is for the purpose of loosening and resetting the forms.

DIVIDING THE CIRCLE INTO QUARTER SECTIONS.

Remove the nails in one half of every fourth piece in the top layer of each circle. This will divide each circle into four equal parts, with lapped joints.

BUILDING THE INSIDE FORM.

A hole 1 inch wide and 3 inches long should now be cut through both layers in the center of each joint. (See fig. 5*b*.) These holes are provided for wedges which are used in fitting or releasing the forms from the wall. The ends of the quarter sections should then be cut off at the outer edges of the wedge holes. This will allow the sections to slide together when they are to be removed from the wall.

When all the wedge holes have been cut and the work of dividing into quarter sections is complete, temporarily nail the quarter sections together at points of division and brace the top circle directly over and 32 inches above the lower one. See that both circles are perfectly level and that the joints in the upper circle are directly above the joints in the lower circle, and then proceed to nail in securely, between the top and bottom circles, 1 by 3 inch studding, 32 inches long, placing the studs carefully plumbed from 12 to 18 inches apart, as shown in figure 5*a*, to keep the iron from bulging.

In nailing on the sheet iron use 6-penny nails, and nail securely. Before starting to nail on the iron, however, see that it is cut to the proper length. The sheet for each quarter section should be just 3 inches longer than one-quarter of the circumference. If several sheets are required to make a single quarter section, they should be carefully riveted together with a double row of flat-headed rivets. Since the quarter sections lap 3 inches, and in removing need to slide

together several inches farther, it is necessary to leave one end of the sheets loose 8 to 10 inches from the end, while at the other end it should be nailed all the way.

Wedges for inside form.—The wedges should be of hardwood, 8 to 10 inches long, 2 inches wide at the narrow end and 4 to 5 inches at the other. In order to make the wedges drive true and hold, it is necessary to put in loose blocks, as shown in figure 5*a* and 5*b*.

BUILDING THE OUTSIDE FORM.

The outside circles are built up and divided into quarter sections just as are the inside circles, but no provision is made for wedges. The sheet iron is made up into quarter sections, 3 inches longer than one-quarter of the outside circumference, to provide for the lap.

Lugs and bolts for outside form.—The quarter sections are joined and drawn together by means of bolts and lugs, the latter made from $\frac{3}{8}$ -inch tire steel and riveted on the forms as shown in figure 5*c*. Note that on one end of the section the lugs are riveted on flush with the edge of the iron, while at the other end they are set in 5 inches from the edge to permit the lap. If preferred, the lugs may be put on the top of the supporting circles instead of on the sheet iron. The lugs should be made about 24 inches long to provide for several rivets. For drawing the sections together use $\frac{3}{8}$ -inch bolts, 5 inches long, with hexagonal heads and nuts and extra long thread. (See fig. 5*c*.) The forms are now ready for use.

The experienced silo builder may leave off the supporting circles from the outside form. For the inexperienced man it is generally safer to provide these supporting circles, as they prevent the sheet iron from drawing at the top when the concrete is being placed.

SETTING THE FORMS.

In building the wall the inside form is used from the footing up. Generally for the first 3 feet of wall the outside form is not needed, the earth wall of the pit serving in place of the outside form. As soon as the wall reaches the top of the ground the outside form must be placed in position. In order to space the outside form exactly 6 inches from the inner it may be necessary to saw a number of blocks 6 inches long and place them at intervals along the bottom to temporarily hold the form in place. As the concrete is filled in these blocks must be removed. Leaving them in the wall might permit air to enter the silo at those points. For spacing the forms at the top a number of pieces of the shape shown in figure 5*d* will be found useful.

The greatest of care must be taken to have both forms level across the top and the sides plumb. If on one side of the silo the forms are higher than on the other they are out of round, and consequently the wall at some places will be thicker than at others, thus making it impossible to build the wall plumb. The diligent use of a plumb bob and a good level to see that the forms are plumb and level at each raising will save much annoyance later.

SCAFFOLDING.

As soon as the forms are in place for the first time, it is well to start the scaffolding shown in figure 8, which supports the forms and from which the work is done. It is less expensive and also more convenient to have the working platform on the inside of the silo rather than on the outside. For this scaffold 2 by 4 inch scantling doubled is the most convenient material, but long straight poles can be used equally well, and frequently at much less expense. It is well to set the poles or scantlings in the ground 4 to 6 inches in order to make them more secure. They should also be securely braced. Figure 8 shows how they are distributed for both inside and outside scaffolds. The number of uprights needed will vary with the diameter; silos of small diameter may require only 9 for the inside, while for large silos 17 or

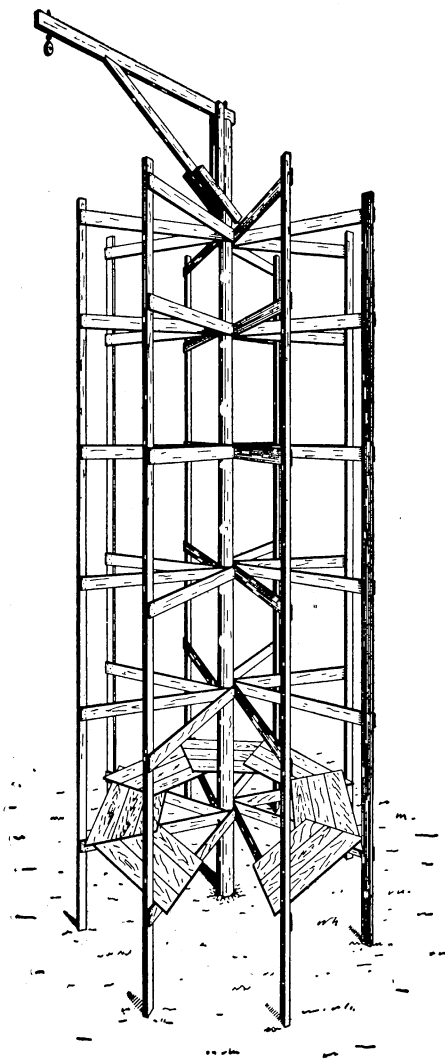


FIG. 8.—Scaffold used in constructing concrete silo.

more may be found necessary. The number needed for the outside scaffold will vary in proportion. The uprights on the inside are set in from the wall 12 inches to permit the removing of the form. If the uprights are set too close to the wall it will cause trouble, as in raising it becomes necessary for one form to pass

by the other. The uprights should be set plumb and with a straight side toward the wall.

REINFORCING.

Concrete, like all masonry work, must be reinforced when subjected to a pulling or bending stress. Concrete of itself has a low tensile strength. Silage is a heavy material and exerts considerable pressure upon the walls. In addition to this pressure of the silage there is also wind pressure, which on occasions is considerable; but the circular walls, together with the numerous strands of wire in the kind of reinforcement recommended, are more than sufficient to guard against failure.

The material used for reinforcement may be steel rods, bars, or ordinary wire, provided the amount used is sufficient to withstand the pressure. The most convenient material to use and one that is readily obtained anywhere at a reasonable cost is the common woven or welded steel hog fencing, 32 or 34 inches wide, with horizontal strands of No. 9 wire. This wire is easily placed in position, and is not easily displaced while filling the form.

Reinforcing to be most effective must be placed near the surface where the pull will come. In a silo wall this is on the outside, so the reinforcing should be placed from 1 to 2 inches inside the outer surface. Since the strength of the wall depends largely upon the reinforcing used, it is never advisable to use old or damaged wire, and in handling the wire care should be taken to avoid kinks and sharp bends. If the silo wall is over 30 feet in height, the first two or three courses should have the fencing doubled to meet the increased pressure.

In the table below is given the length to which to cut the fencing. The lengths given allow 6 inches for use in fastening ends together securely so that there is no chance of slipping.

Each course of reinforcement should be securely laced to the preceding course with No. 16 soft wire.

Length to which to cut fencing for reinforcing concrete wall.

Diameter of silo.	Length of fencing re- quired to make cir- cumfer- ence. ¹	Diameter of silo.	Length of fencing re- quired to make cir- cumfer- ence. ¹
<i>Feet.</i>	<i>Ft. In.</i>	<i>Feet.</i>	<i>Ft. In.</i>
10	34 3	15	50 0
11	37 5	16	53 1
12	40 7	17	56 3
13	43 8	18	59 5
14	46 10		

Includes 6 inches for fastening.

Special care must be taken to have the reinforcing around the doors as strong as in any other part of the wall. Figure 9 shows how a five-eighths inch rod, or its equivalent, should be placed on either side of the opening about 2 inches from the door form. The horizontal strands of the fencing are cut to admit the door form, and the ends are securely wound around the iron rods. The rods should

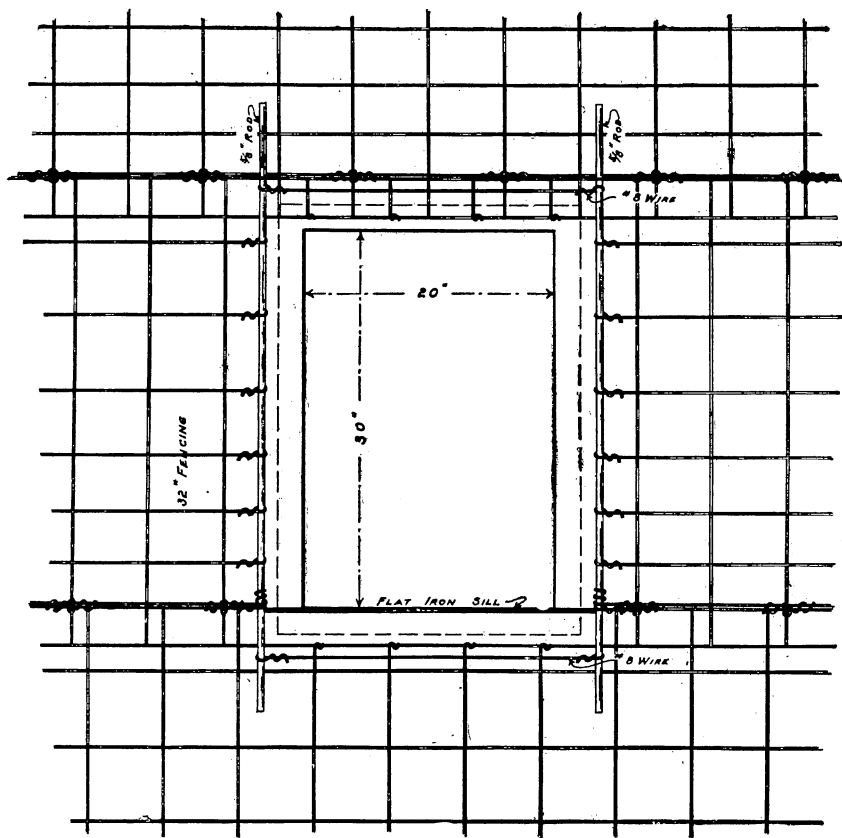


FIG. 9.—Position of reinforcing rods around door opening.

extend 6 to 8 inches above and below the door openings and should be tied with several strands of No. 9 wire.

PREPARATION OF THE CONCRETE.

CEMENT.

Only the best Portland cement on the market is suitable for building thin reinforced walls such as are used in silo building. Portland cement comes packed in either barrels or sacks; four sacks equaling a barrel. In buying cement care should be taken to see that the stock is fresh. When cement is stored where it can absorb moisture it

becomes lumpy and hard and unfit for use. Hardness, however, is not always an indication that the cement is unfit for use, as it may become hard if stored under considerable pressure, and if such pressure is not combined with a moist condition the cement may again be pulverized and used. Unless there is a good dry place in which to store the cement it should not be purchased until it is to be used. If circumstances require storing temporarily, select a dry place protected from the weather and pile the cement on a board floor.

SAND.

Sand for building a silo should be coarse, and above all it should be clean—that is, free from clay or vegetable matter. A fine sand is objectionable because it does not make as strong a wall as coarse sand and also because it requires more cement. A mixture of coarse and fine sand, however, will make good strong concrete. A common method of testing sand for vegetable loam is to take handfuls of the moist sand from the bank and rub between the hands. If the palm and fingers are covered with a film of pasty slime, the sand contains vegetable matter and should be washed before using.

CRUSHED STONE OR GRAVEL.

The bulk of concrete consists of gravel or crushed stone that is added to the sand and cement. Other materials, such as pieces of hard brick, oyster shells, and cinders, can be used instead of the crushed rock. Crushed stone is the best because it is more sure of being clean and of the right size. Gravel taken from a creek is often coated with clay loam, which prevents the cement from making a good union, and very often it contains particles that are too large or of a crumbly character. Such gravel should be run over a screen and washed before using.

Soft granite, shale slate rock, or dusty cinders are not desirable. Whatever material is used should be free from dust and dirt; it should not easily crush and disintegrate, and should be suitable to give a good strong union with the cement.

In some localities there are natural deposits of gravel containing varying proportions of sand. If clean and not too coarse, such gravel is well suited for silo building; but in using this material it is never safe to assume that the proportion of sand to gravel is correct until a quantity has been run over a screen ($\frac{1}{4}$ -inch mesh) and the exact proportions determined. Usually the gravel contains too much sand.

For the foundation the stone may be as large as will pass through a $2\frac{1}{2}$ -inch ring, while for the main wall of 6-inch thickness the size should not exceed $1\frac{1}{2}$ inches. A mixture of particles of various sizes from $\frac{1}{2}$ up to $1\frac{1}{2}$ inches makes the strongest wall.

WATER.

The water used for mixing concrete should be clean and free from alkalies and acids. The drainage water from the barnyard or water from a muddy stream is unfit for use.

PROPORTIONS.

For the foundation use a 1:3:6 mixture; that is, a mixture of 1 part cement, 3 parts sand, and 6 parts crushed rock. For the main wall use a 1:3:5 mixture, or 1 part cement to 3 parts sand and 5 parts rock. These proportions apply when all the material is first class. If the sand is fine, the proportion of cement must be increased 10 to 15 per cent to insure a strong mixture.

The mixed concrete should be placed promptly, after mixing,

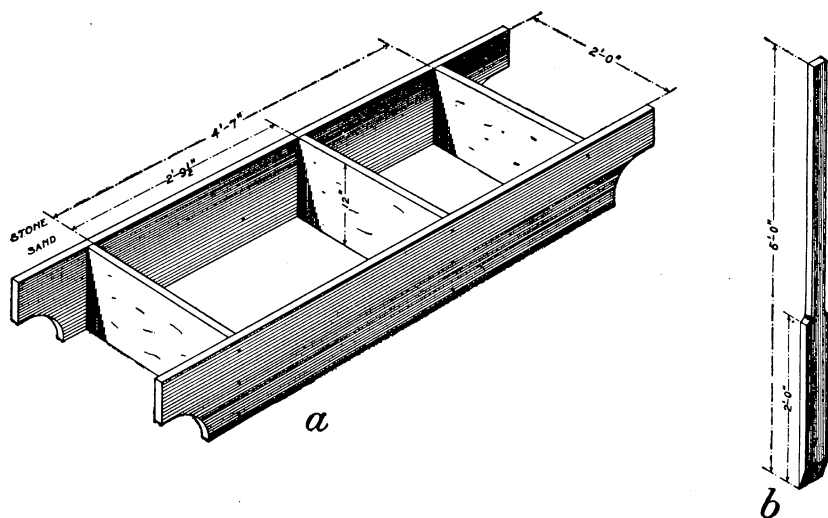


FIG. 10.—Measuring box for concrete materials.

before it begins to set; therefore in silo building it is not advisable to mix up very large batches at a time. After the silo wall is above a man's reach as large a batch as ought to be attempted is what is known as a two-bag batch, or the quantity of concrete that requires two bags of cement.

MEASURING.

The measuring of the different ingredients for concrete is an important part of the work and requires care and attention. The most accurate way to measure sand and gravel for such a batch is to use a frame or measuring box, as shown in figure 10*a*. For a 1:3:5 mixture this frame should measure, inside, 4 feet 7 inches long, 2 feet wide, and 12 inches deep. On the inside of the frame, 21½ inches from one end, a partition is placed crosswise of the box. When measuring the rock this whole frame is filled level full, and for measuring the sand use only the largest division of the frame level full.

MIXING BOARD.

The first requirement for mixing is a level, water-tight platform. The smallest size found convenient in silo building is 9 by 10 feet. With a board of this size one batch can be put into the forms while another is being prepared; the process of filling is made continuous, and all the working force is constantly employed. The platform or mixing board should be built of dressed 1-inch lumber nailed to a sufficient number of 2 by 4 inch cleats to prevent sagging. If 2 by 4 inch pieces are nailed around the edge of the board, they will help prevent loss of material in the process of mixing.

The platform should be placed with one end not over 2 feet from the silo wall, so that the mixture can be shoveled from the board into the buckets used in hoisting, thus avoiding all carrying. The position of the mixing board should be determined before any of the sand and gravel are delivered, so that these materials can be piled in the most convenient place.

A water-tight barrel, filled with water before each batch, should be placed conveniently at one side of the mixing platform. Also an ordinary 2-gallon water pail is needed. For the mixing and handling of the concrete square-pointed, short-handled shovels are best. An ordinary garden rake and two field hoes should also be provided. For bringing the sand and gravel to the concrete board two wheelbarrows should be supplied. With this preparation the work of mixing should proceed without interruption.

MIXING.

Place the measuring box at the end of the board farthest removed from the silo, and with the wheelbarrows bring up the sand and fill the largest division of the frame level full. (See fig. 10a.) Then lift the frame off and set it to one side, leaving the required amount of sand on the board. Spread the sand out evenly to the depth of not over 4 inches and over this distribute the two bags of cement. Two men with the square-pointed shovels then turn the mixture over until it is a uniform color, showing that the mixing is done well. In turning the mixture over the men should shovel from the same side of the pile. As each shovelful is turned the shovel should be so held that the material is scattered instead of falling in a body. If a third man is available, he can assist in the mixing by raking over the pile as it is being turned. Turning the pile over in this way three times should be sufficient to mix thoroughly the sand and cement, but if it is streaky and of uneven color it must be turned again.

At the last turning the mass should be rounded up into a low crater-like pit, and the water added by pouring it into the crater. With the field hoes the sides and bottom of the crater are pulled in gradually, water being added until the whole mass is uniformly wet and about the consistency of thin mortar. Spread the pile out so that it will

not be more than 3 or 4 inches deep, set the measuring frame over it, and fill the latter level full with the crushed rock or its equivalent. Each barrowful of rock should be thoroughly wet to wash off the dust before dumping into the measuring frame. When filled, lift off the measuring frame and shovel on top of the pile the mortar that is not covered. Turn this mass over at least three times and in such a way that the last turning will place it next to the silo convenient to the hoisting buckets. During this mixing, water may be added if required to bring the mass to the proper consistency.

The most convenient device for carrying and pouring the concrete into the forms is an ordinary coal scuttle, and if care is taken not to overload them, three will last for the whole job. For elevating the buckets set up a rope and single pulley, such as is used over open wells.

FILLING THE FORMS.

In filling the forms, only a few inches in depth should be filled in at one place at a time. Depositing a great quantity of concrete at one place puts a heavy strain on the forms and has a tendency to force them out of plumb. As the concrete is put into the form it should be spaded with a piece of 1 by 3 inch board, sharpened to a bevel edge as shown in figure 10*b*. The purpose of the spading is to remove all air bubbles and avoid the formation of cavities. On the other hand, in a wet mixture as used in silo building the spading must not be overdone, or the heavier rock will sink to the bottom and the cement and water will rise to the top.

The exterior surface can be kept smooth by greasing the outside form with soap or some cheap oil or grease. To be effective this grease coat must be renewed at each raising of the forms. No grease should be used on the inside form, as this surface is to receive a brush coat of pure cement wash. Small particles of cement will adhere to this form each time it is raised, and before it is used again these should be removed with a broom or a wooden trowel. If these are not removed an undue amount of concrete will adhere, and this will result in an unnecessarily rough wall.

As the forms are raised the fresh wall is constantly exposed to the drying air and sun, and there is danger of the surface drying and curing too rapidly for the interior of the wall, causing cracks. To prevent this the wall should be soaked with water several times a day for several days, and when possible the wall should be protected with canvas or burlap thoroughly wet.

When the forms have been filled for the day do not smooth the top with a trowel, but leave it as rough as possible. A good plan is to roughen the top surface just as the concrete starts to set. Before putting fresh concrete on this wall the next day, the top surface should be soaked with water and then sprinkled with raw cement,

which will help in making a good union between courses. The forms must not be removed for at least 5 hours after filling.

At the end of each day's work the mixing board and all tools should be washed free from cement; otherwise the next day's work will be tiresome.

INSIDE SURFACE FINISH.

A brush coat of cement wash should be applied as soon as the form is raised and before the wall has had a chance to dry. This coat of cement helps to make the wall less porous and therefore more nearly air and water tight. The wash is prepared by mixing together cement and water to the consistency of thick lime whitewash, and is applied with a whitewash brush in the ordinary way. If the wall has had time to dry it should first be drenched with water.

After this coat of cement wash has been applied the whole interior should be painted with coal tar thinned with gasoline. The coal tar makes the wall impervious and also protects it from the action of acids which develop in the silage. It should be renewed from year to year as may be required. The application of the coal tar may be left until the wall is complete, but should be done before removing the interior scaffold.

RAISING THE FORMS.

Before loosening the forms for raising, a straight edge should be laid across their top and leveled, and marks made on the uprights to show the position of the next set of supports, which will be just 3 inches below the top of the forms. If this is done carefully there will be little trouble experienced in resetting the forms.

The outside form can then be loosened and lifted to the top of the wall and rested there while the supports are nailed in place on the outside scaffold. The form is then let down on the supports and the bolts on the lower edge are drawn up until the form is tight against the wall. The remaining bolts are drawn up carefully while a plumb line is used to determine where and how much to tighten. When the outside form is in place, and before raising the inside form, is a convenient time to place the reinforcing.

Next, the wedges are drawn on the inside form, the sections lifted and rested on the top of the wall, while the cross supports are nailed in place and the working platforms relaid. This done, the sections are lowered into place and the wedges set, care being taken to have the form tight against the wall and perfectly plumb.

This order of procedure, raising the outside form first, has been found the more convenient in actual practice. If for any reason it is preferable to raise the inside form first, care must be taken not to drive the wedges tight enough to injure the green wall. If the outside form is raised into position first, it helps to support the freshly built wall while the wedges are being driven. In raising the forms and in

the process of building, care should be taken to avoid jarring the wall by heavy pounding, which is likely to injure the concrete in the process of setting.

Time and labor may be saved by raising all the four sections of the form at one time by the use of four sets of double pulleys, such as are used for stretching barb wire, and a rope fastened around the center of each section.

Under the most favorable conditions at least five hours should elapse between the time of filling and loosening the forms. A good

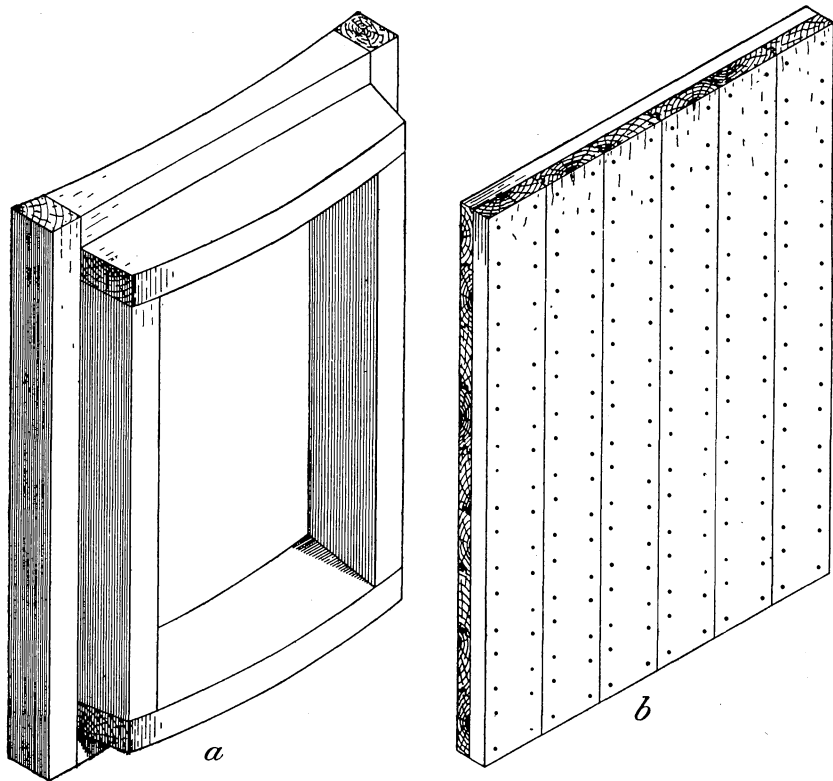


FIG. 11.—Door and form for door opening.

working plan is to raise and fill the forms in the morning and then leave them undisturbed until the next morning.

DOORS.

For making the door openings, a form should be made which can be set in between the large wall forms. This form is built of such size and shape (see fig. 11*a*) that when the concrete is molded about it a 2-inch rabbet is formed around the inside of the opening into which a wooden door can be set, this door being held in place by the pressure of the silage on the inside. In order that the form may be easily removed without injury to the wall, the top and sides are built with a slight taper, which permits the form to slip inward

when lightly tapped on the outside. The bottom pieces or sill of the form should be left flat. All the surfaces should be dressed with a plane and greased before using. In placing the concrete about the form, considerable care must be taken to have it well worked in

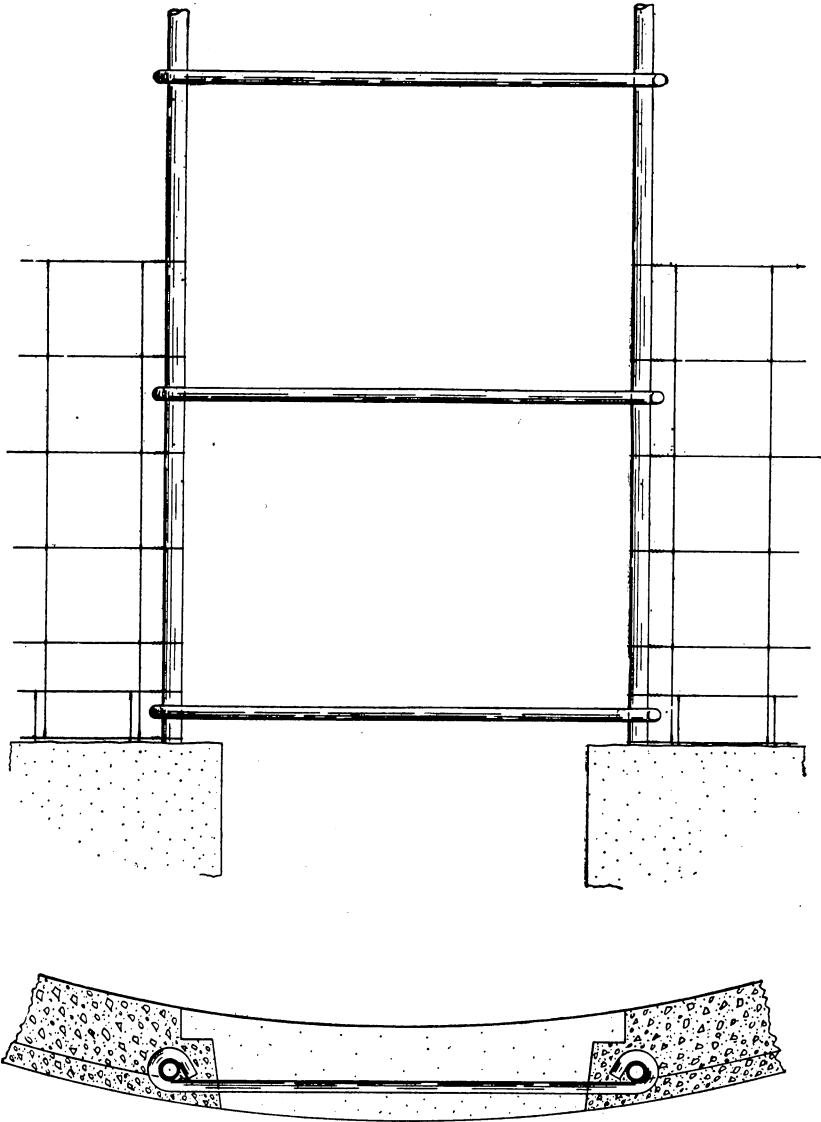


FIG. 12.—Detail of reinforcement for continuous door opening.

under the sill, or a rough job will be the result. The sills of the doors, especially of the bottom door, receive much wear, and should be protected by a piece of angle or strap iron, which is inserted at the time the bottom 2 by 2 inch piece is placed.

Unless it happens that the position of the doors exactly coincides with the alternate raising of the wall forms, two forms will be required. The top and bottom pieces of the forms are curved to the circumference of the silo, and should be marked off with the slat shown in figure 6 in the same manner as the templet.

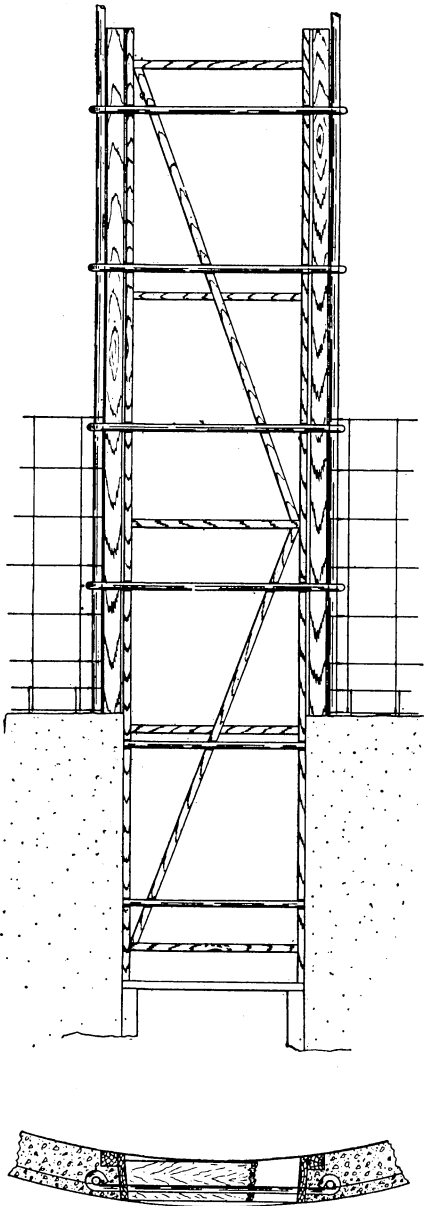
Figure 11*b* shows the design of the silo door. It is made by nailing together two thicknesses of flooring with tar or building paper between. The doors are held in place by the pressure of the silage.

CONTINUOUS DOOR.

Many prefer a continuous door opening on account of the ease with which the silage can be removed through such an opening. A continuous doorway can be made by setting 1-inch pipes vertically, one on each side of the opening, 28 inches apart. These pipes should extend into the foundation about 1 foot. The reinforcing wire is fastened securely to them, and three-fourths or seven-eighths inch rods extending horizontally across the doorway are hooked around the pipes every 20 inches. These rods serve the purpose of preventing the door jambs from spreading and also carry the strain of the reinforcement across the door opening. (See fig. 12.) When the silo is completed, the rods form the rungs of a ladder for the silo.

Fig. 13.—Detail of form for construction of continuous door opening.

The door itself may consist of 2-inch select planking 10 or 12 inches wide, cut in 2-foot lengths; or a door may be made by nailing together two thicknesses of 1-inch boards with building paper between them. (See fig. 11*b*.) These



planks, or these doors if such are used, fit into a rabbet on the inside edge of the doorway. This rabbet is formed in the concrete by the use of a form to which are attached 2 by 2 inch strips, as shown in figure 13.

FLOOR.

For the floor, use the same mixture suggested for the foundation wall, and lay it about 4 inches deep. Tamp this down well, and over it put a $\frac{1}{2}$ -inch surface coat of mortar made by mixing 3 parts sand and 1 part cement. The outlet for the tile drain must be provided for at the time the foundation is put in, but it is suggested that the laying of the concrete floor be left until all the other work of building has been completed.

ROOF AND CHUTE.

For attaching the roof to the silo, a number of $\frac{1}{2}$ -inch bolts should be set

in the top of the wall for bolting down the plate. (See fig. 14.) These bolts are best made from $\frac{1}{2}$ -inch rod iron cut into 18-inch lengths, one end to be threaded and the other bent at right angles $2\frac{1}{2}$ inches from the end to prevent the bolt from turning or pulling out.

If the silo is roofed, provision must be made for a door opening for filling the silo. Figure 30 shows a good type of roof with a door in the gable.

To prevent loss in removing the silage, the doors should be inclosed in a chute. For entering the silo, a ladder should be built on the inside of the chute. For attaching this ladder and chute to the silo,

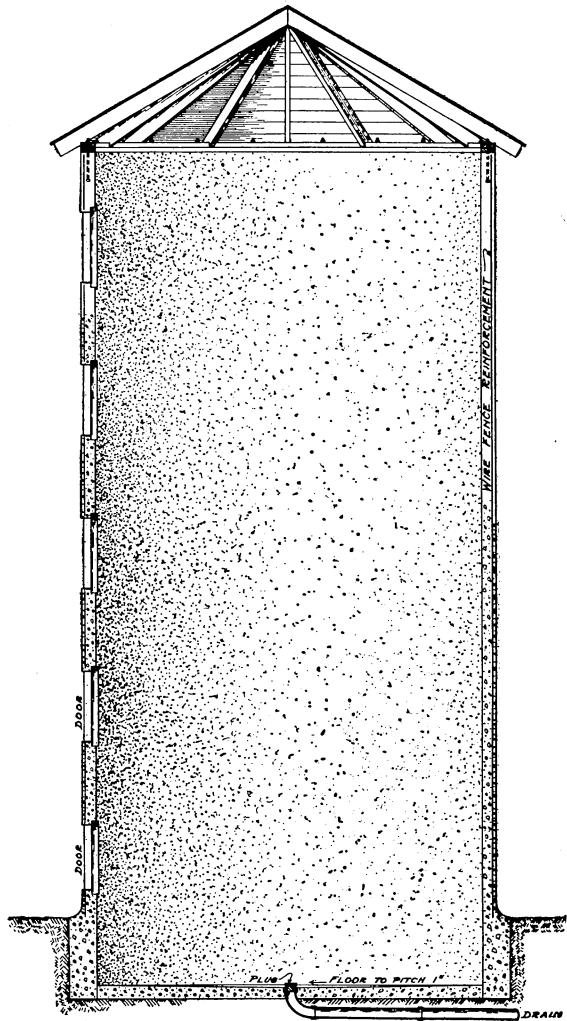


FIG. 14.—Sectional view of concrete silo.

bolt holes may be drilled into the concrete wall after it is built; or at the time of building square-taper wooden wedges may be set in the wall as the concrete is being filled in. If these wedges are well greased before putting into the wall, less trouble will be experienced in punching them out.

THE STAVE SILO.

FOUNDATION.

The materials to be used for the foundation are limited to three in number—brick, stone, and concrete. Where hard-burned brick can be secured cheaply, as is often the case near brickyards, it can frequently be used to advantage for a foundation. It should be laid in cement rather than in lime mortar. If the foundation extends more than 1 foot above the surface of the ground it should be reinforced with heavy wire.

Stone makes a good foundation, but concrete is preferable under most conditions; it is not only stronger, but also generally cheaper than brick or stone.

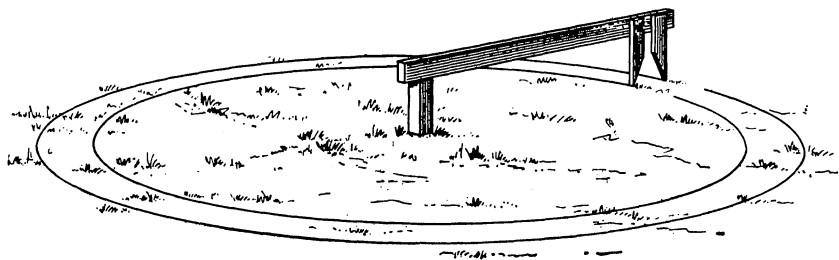


FIG. 15.—Laying off the foundation for a stave silo.

The practice of setting stave silos directly on the ground without any foundation is indefensible when the structure is wanted for several years. The bottoms of the staves will soon rot, while the remainder of the silo may remain in good condition.

LAYING OFF THE FOUNDATION.

Remove any grass or rubbish which may be found at the site of the silo wall and smooth the surface of the ground. Drive a stake firmly in the ground at the center of the proposed silo. Saw off this stake at the height desired for the foundation wall, which should be at least 1 foot above the surface of the ground. One end of a straight 2 by 4 inch scantling, a little longer than is necessary to reach from the center of the silo to the outside of the foundation wall, should be nailed on top of the stake with a 40-penny spike. This spike then marks the exact center of the silo. From it measure on the scantling the distance to the inside and outside of the foundation wall and, having nailed markers on as shown in figure 15, lay off the foundation. The inside of the foundation wall should be 6 inches nearer the center of the silo than the inside of the staves.

Where the ground on which the silo is to be located is not level, the markers can be lengthened by holding a longer board against either marker, as indicated in figure 16, moving it up or down to keep it touching the ground, but care must be taken that the scantling is held level.

CONSTRUCTION OF THE FOUNDATION.

Where stone or brick is to be used, the earth in the bottom of the silo, except where the center stake stands, may be dug out before the wall is built, thus allowing greater convenience in building the wall.

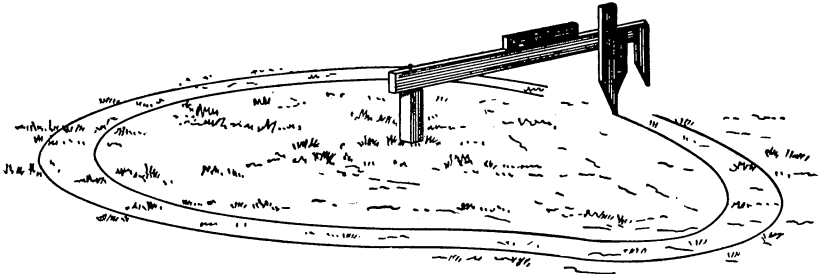


FIG. 16.—Laying off the foundation on sloping ground.

The earth should not be dug out deeper than 4 inches above the bottom of the wall. Where concrete is to be used, this excavation should not be made until the wall has been finished and the position of the staves marked on the top of the foundation wall.

Concrete foundation.—For a concrete foundation, a circular trench must be dug before any of the earth is removed from the center (see fig. 17). The earth between the two lines that mark the inside and outside of the foundation should be taken out until firm ground below frost line is reached, care being taken to cut the sides of the trench plumb and to leave the bottom level.

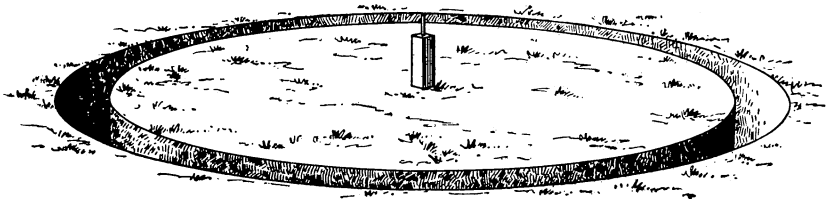


FIG. 17.—Trench for concrete foundation.

Preparing the concrete.—The concrete is prepared in just the same way as for the construction of a concrete silo. Directions will be found on page 20.

Filling the trench with concrete.—Put in the first layer about 6 inches deep and thoroughly tamp the concrete until water appears on the surface. A good tool for tamping may be made of a piece of 4 by 6 inch lumber, 2 feet long, with a hole bored in the center of one end to receive a round handle 4 feet long. When the second layer is put on, the surface of the first layer should be per-

fectly clean and rough, and if dry it should be sprinkled with water. Particular care should be taken to keep all dust and loose soil from the surface of each layer, as these prevent perfect adhesion.

Building forms.—After the trench is filled to the surface of the ground, drive 2 by 4 inch stakes half an inch from the foundation on the inside and 2 feet apart all the way round. (See fig. 18.) With a straightedge placed level—one end on top of the center stake and the other against the side of the form stake—mark on the form stake the desired height of the wall. Mark thus on every second

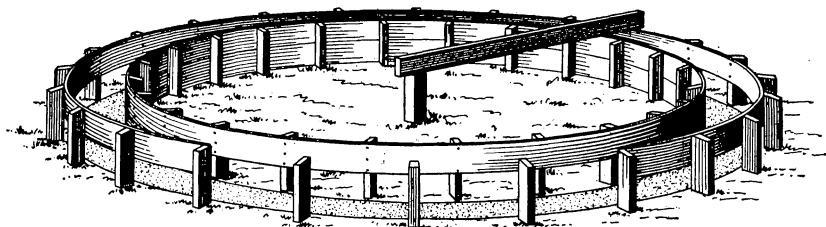


FIG. 18.—Form for foundation above ground partly boarded up.

stake. Take pieces of lumber one-half inch thick by 6 inches wide, preferably green, with straight edges, and bend around outside of these stakes, nailing the boards to the stakes, with the top edge at the marks. Then saw off the tops of the stakes above the boards. (The necessity for this sawing may be avoided by driving down the stakes beforehand to the exact height.) After the space from the top board to the ground has been boarded in, drive stakes in a similar manner for the outside form half an inch from the concrete. Drive these stakes so that the scantling resting on the center stake

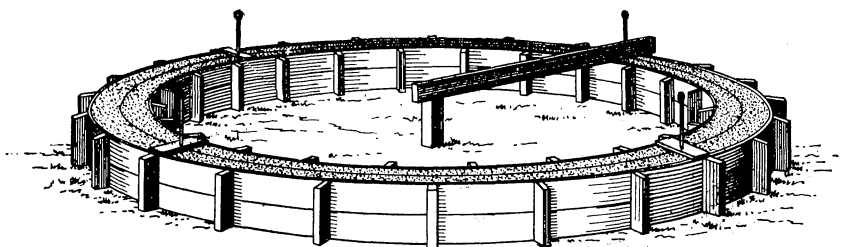


FIG. 19.—Form filled with concrete showing eyebolts and slats in place and circle to mark position of staves.

and the inside form, as shown in figure 18, will just clear the tops. Board up these stakes on the inside, making the top of the outer form level with that of the inner.

At several places nail slats across the top of the form to keep the inner and outer circles the proper distance apart. After all the boards are on, the form is ready to be filled with concrete. (See fig. 19.)

Filling the form.—Eyebolts half an inch in diameter, from 20 to 24 inches long, and about 5 feet apart, with a hook or elbow on the lower end, should be placed 8 inches from the inside of the foundation

and held in a vertical position by boards fastened across the top of the form. The bolts may be put through pieces of board, as shown in figure 19, and the boards afterwards split away with an ax. These bolts should extend 8 or 10 inches above the top of the wall, and the concrete filled in around them. They are to be used, after the silo is completed, for securing the wooden part of the structure to the foundation, the staves adjoining the eyebolts being securely fastened to them.

If the wall extends more than 1 foot above the surface of the ground, it should be reinforced by embedding in the concrete, every 8 inches above the surface and near the outer edge, two or three strands of wire with ends tied together. After tamping each 6-inch layer of concrete, work a spade between the concrete and the form to force the coarser materials away from the boards, thus leaving smooth-surfaced walls.

When the concrete is within 1 inch of the top, finish with mortar made by mixing 1 part of cement to 3 parts of sand, and strike off level with the top edges of the form.

After the concrete has set and before removing the center stake, mark a line with a nail, pencil, or crayon entirely around on top of the foundation wall 6 inches from the inner edge to show where the inside edge of the staves will come. (See fig. 19.)

The dirt inside the foundation may next be dug out to 4 inches above the bottom of the wall. It should be borne in mind, however, that the bottom of the silo should not be more than 5 feet below the lowest door and that the bottom of this door will be 1 foot above the foundation.

FLOOR.

The floor should be constructed in the same way as for a concrete silo. Directions are to be found on page 29.

THE STAVES.

LUMBER.

Cypress, long-leaf pine, white pine, cedar, and California redwood are good materials for stave silos. It is important that the staves be straight and free from sapwood, loose knots, and waney edges.

PREPARING THE STAVES.

Staves should be made of 2 by 4 or 2 by 6 inch scantling, the latter being preferable, particularly for the larger silos. They should be of the same width and thickness and should be dressed on all sides, the edges being left square. It is considered necessary by some that the edges of the staves be tongued and grooved, but satisfactory results can be obtained by using square-edged staves, and at less expense.

After the staves are squared at the ends, holes should be bored in the edges from 4 to 6 feet apart with a $\frac{1}{2}$ -inch bit. These holes are

made on one edge only of each stave, and must not be in line in adjoining staves. They should be about 1 inch deep in staves 4

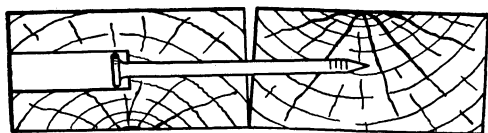


FIG. 20.—Cross section showing how two adjoining staves are spiked together.

inches wide, and about 3 inches deep in staves 6 inches wide. One of these holes should come within a foot of each end of the stave. Bore the holes perpendicular to the edge of the stave, to avoid having

the silo thrown out of plumb. The purpose of these holes is to allow spiking the staves together when set up. The spike is driven to the bottom of the hole, and passes through the rest of that stave and into the adjoining stave, as shown in figure 20. Care should be taken not to put any spikes in those portions of staves which are to be cut out for doors.

It is preferable that each stave be in one piece, but where this is impossible the staves should be of two pieces of different lengths, splined together by making in the ends to be joined a saw cut 1 inch deep and parallel to the sides of the stave and inserting a sheet iron spline (preferably galvanized), as shown in figure 21.

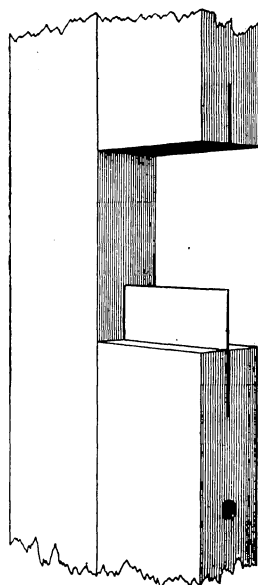


FIG. 21.—Method of splicing ends of staves.

CUTTING THE DOOR STAVE.

Before the staves are put up it is necessary to decide how many doors the silo should have, that a door stave may be prepared. The table on page 8 will assist the builder in determining the number of doors and the distance between them. When this has been done, the location of the doors is laid off on a stave and saw cuts are made halfway through

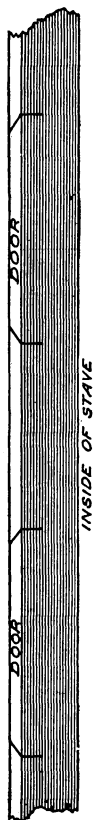


FIG. 22.—Stave partly cut through for doors.

for the entrance of the saw in cutting out the doors after the staves are set up. The cuts should be made at a slant of 45° on the edge of the stave but horizontal on the front, as shown in figure 22. (See

also fig. 28.) The object of the slanting cut is to make the doors removable only toward the inside of the silo, and so that when it is full the pressure of the silage will hold the doors in place. The cut for the bottom of each door should slant downward from the outside of the stave, and the cut for the top of the door should slant upward.

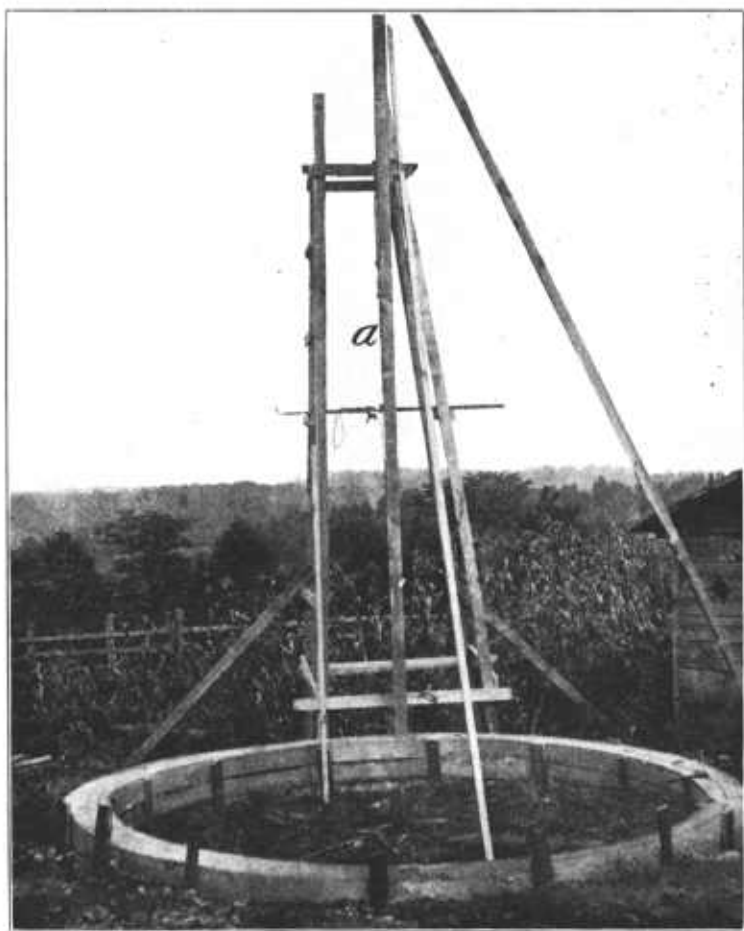


FIG. 23.—The first stave (a) in position.

To prevent this stave from breaking while it is being handled, a slat should be nailed on one side of it. This slat should be removed after the stave has been put in position.

When the staves are being put up, the door stave should be located at one side of the place where the doors are to be cut. After the hoops are put on the silo, a handsaw can be inserted in the saw cuts of the door stave for the purpose of sawing out the doors.

SETTING UP THE STAVES.

In order to nail the staves together at the top when they are being put up, it will be necessary to provide a scaffold. Where the silo is not to be over 25 feet high, a stepladder, as shown in figures 23 and 24, may be used. As the staves are put up the ladder can be moved along and kept in the right place from which to work.

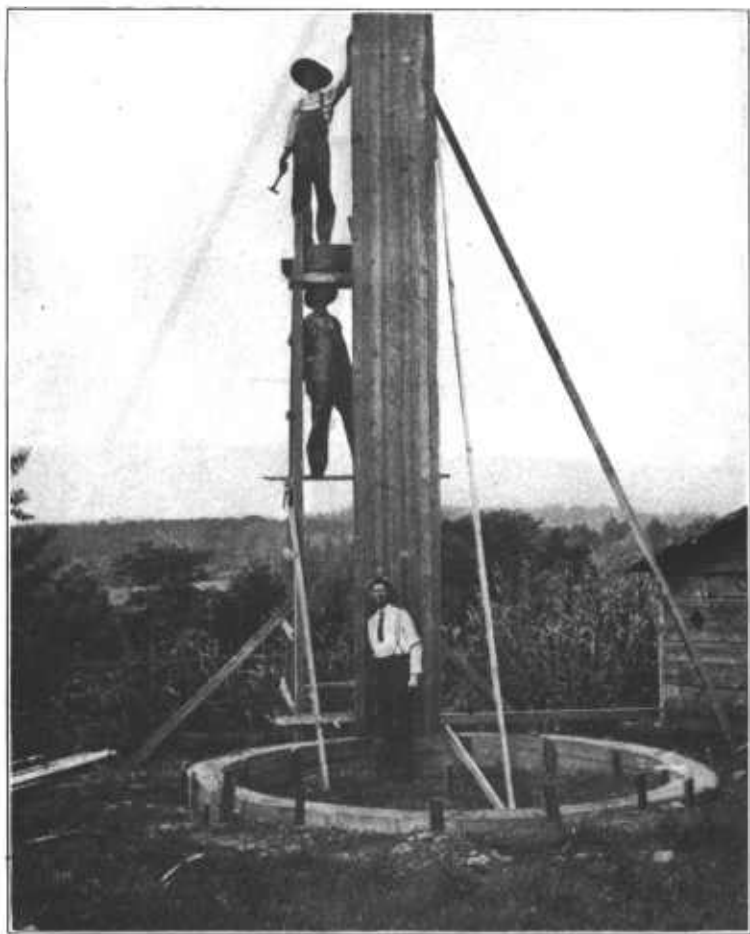


FIG. 24.—Several staves in position.

The first stave (fig. 23) should be placed with its inner face on the line (fig. 19) 6 inches from the inner edge of the foundation. It should be plumbed in both directions and securely fastened at top and bottom. For this purpose use braces nailed to stakes driven firmly in the ground or to some adjacent building, as shown in figure 23. If this is not done the silo will be out of plumb.

The next stave is then set up and nailed to the first with 30 or 40 penny spikes. These spikes are started in the holes previously

bored (fig. 20) and driven home with a driftpin. The spikes must not be driven at an angle up or down, for either of these will throw the silo out of plumb.

Other staves should be put up as above described and as shown in figure 24 until the place is reached where the doors should be. The door stave, cut as previously described, should then be nailed in

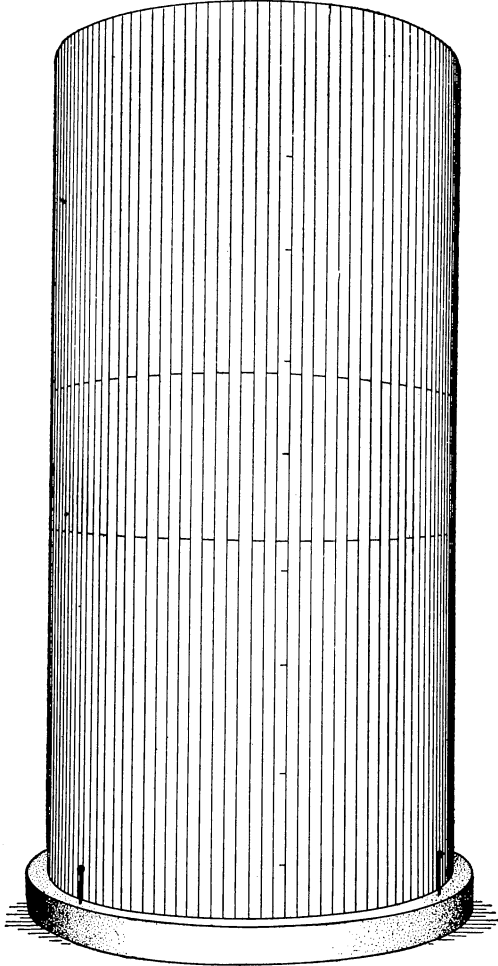


FIG. 25.—All the staves in position ready for the hoops.

position and the remaining staves set up. In setting up spliced staves the longer and the shorter staves should alternate. (See fig. 25.) Ordinarily it will only be necessary to have staves of two lengths, as, for instance, 16 feet and 12 feet for a 28-foot silo. Figure 25 shows all the staves in position ready for the hoops. The junction points of top and bottom pieces are shown; also the door stave with saw cuts part way through it.

THE HOOPS.

The hoops should be made of $\frac{3}{4}$, $\frac{5}{8}$, and $\frac{1}{2}$ inch rods, in sections from 10 to 16 feet in length. The ends of these rods should be threaded 6 inches so that they may be joined together by means of lugs. For

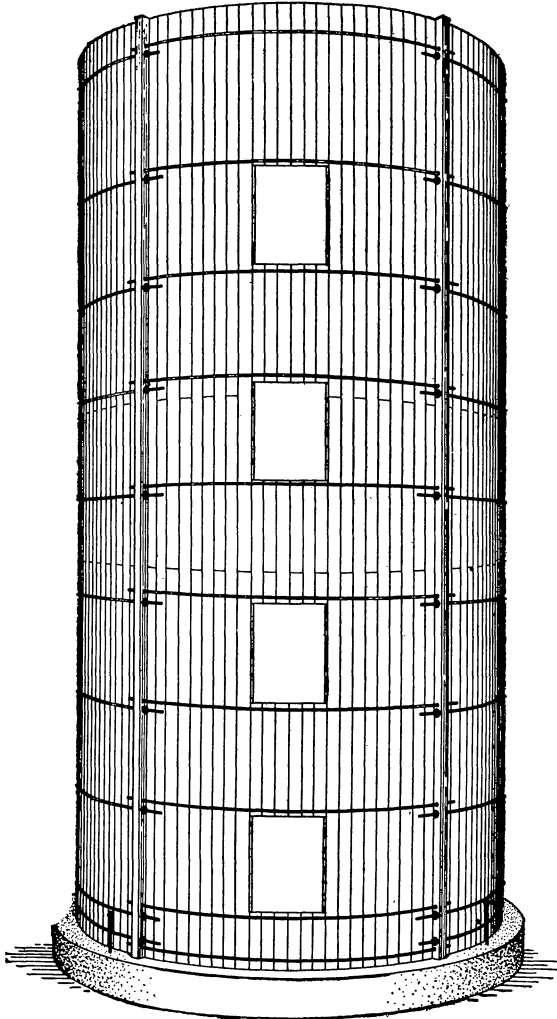


FIG. 26.—Joining hoops without lugs.

silos smaller than 14 by 30 feet the lower hoops should be of $\frac{5}{8}$ -inch rods and the upper of $\frac{1}{2}$ -inch. For silos larger than 14 by 30 feet the lower hoops should be of $\frac{3}{4}$ -inch and the upper hoops of $\frac{5}{8}$ -inch, or if three sizes of hoops are used, the lower ones should be of $\frac{3}{4}$ -inch, the middle hoops of $\frac{5}{8}$ -inch, and the upper of $\frac{1}{2}$ -inch rods.

PUTTING ON THE HOOPS.

Two hoops should be placed below the first door, two between doors all the way up, and two above the top door if this space is more than 2 feet; if less than 2 feet, one will be sufficient. Three or four hoops should at first be put on at the bottom and tightened

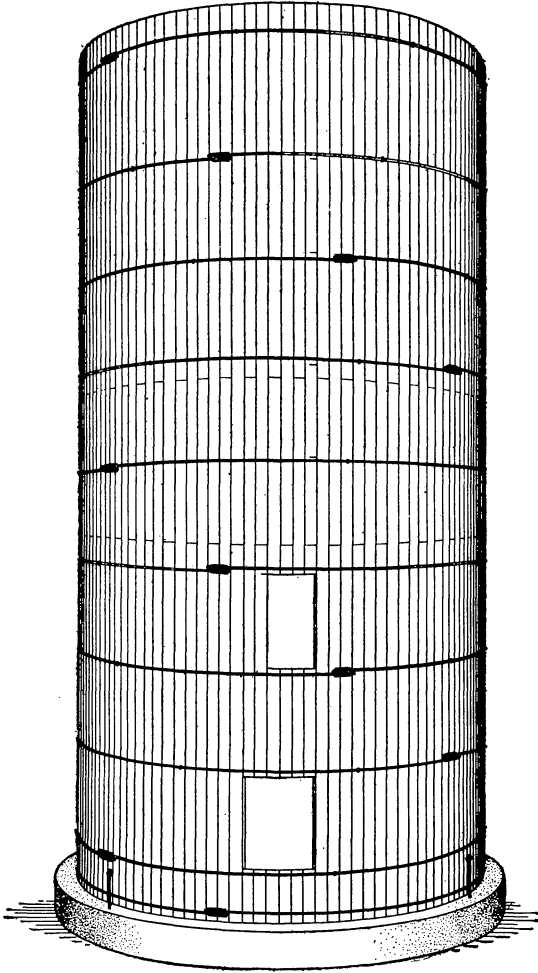


FIG. 27.—Sawing out the doors.

up. Planks can then be thrown across the top of the silo to serve as a scaffold, so that the top hoop may be put on and tightened. The other hoops should then be put around the silo loosely, within reach of the ground, after which they are pushed up to the proper position with slats and from a ladder they are made fast by stapling them to the silo. When all the hoops are in position they should be tightened

until the staves are pressed close together. Staples should then be driven over each hoop 2 or 3 feet apart so as to hold the hoops in the proper position in case they get loose.

JOINING HOOPS WITHOUT LUGS.

It is sometimes very difficult to get lugs for the hoops. In such cases 4 by 6 inch timbers may be put in instead of ordinary staves

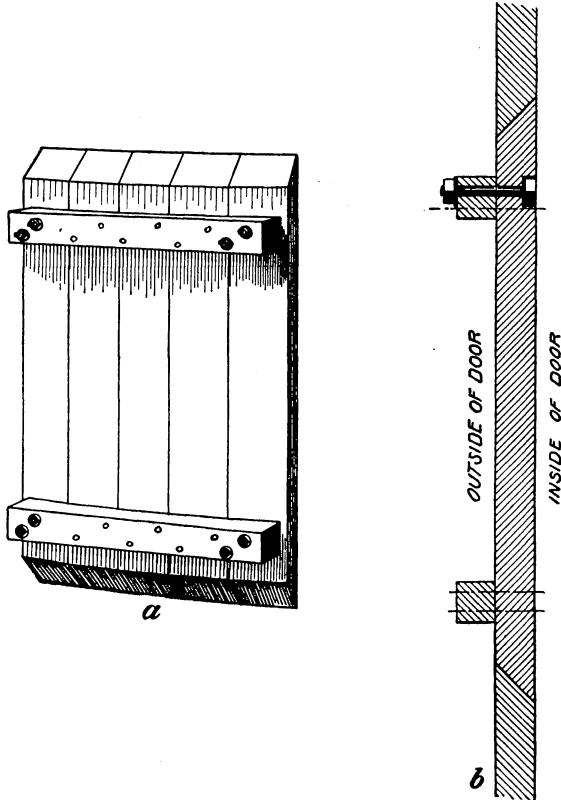


FIG. 28.—The finished door: *a*, Door showing outer face and cleats; *b*, section of side wall showing how door fits.

at the three or four points where the hoops will join. These timbers should be placed with the 4-inch face flush with the staves on the inside and they will extend 4 inches beyond the wall on the outside. Through these outside projections holes should be bored to receive the hoops, and the ends may be fastened with nuts. Large iron washers should be used under the nuts. Such a method of connecting the hoops is shown in figure 26, but its use is advised only when the lugs can not be obtained.

THE DOORS.

SAWING OUT AND MAKING.

After all the hoops are tightened, saw out the doors, beginning with the stave previously cut. The illustration (fig. 27) shows the lower door completely cut and the second one partly cut. The doors should be about 20 inches wide and 30 inches high. The exact width will of course be determined by the width of the staves.

Two cleats, 2 by 4 inches, with one edge cut to the circle of the silo, should be nailed and bolted on the outside of each door (fig. 28) with the nuts on the outside and the bolt-heads sunk flush with the inner surface. The bolts should be $\frac{3}{4}$ inch by 5 inches.

Four bolts in each cleat (two at each end) will be sufficient; the cleats may be nailed to the other strips. After the doors are cut, bolt the silo to the eyebolts shown in figure 19.

A CONTINUOUS DOOR.

To construct a continuous door for a stave silo, a door-frame should be made of 4 by 6 inch timbers which are kept 20 inches apart by means of pieces of pipe and are fastened together by means of bolts passing through the posts and pipes, as shown in figure 29.

Iron washers should be placed between the ends of the pipe and the timbers to prevent the pipe from sinking into the timber. Washers should also be used under the bolt-heads and nuts.

When the door frame is complete, it should be put in position, plumbed, and securely braced, after which the staves should be put up, as previously described. The doorposts should be flush with the staves on the inside. On the outside they will project beyond the staves, and holes should be bored in these projections to permit the hoops to pass through.

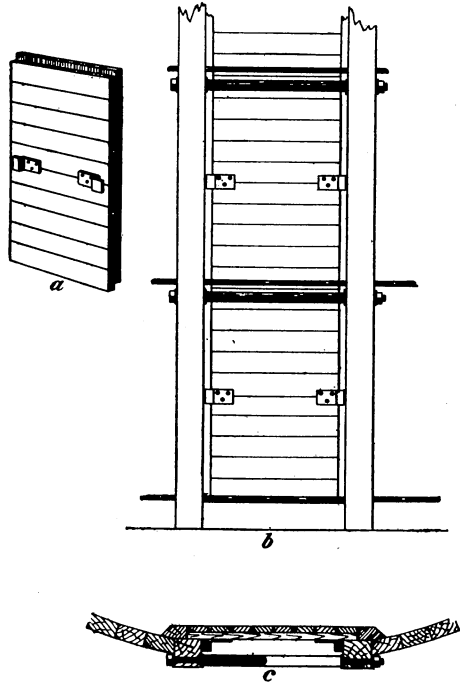


FIG. 29.—A continuous door: *a*, A section of the door; *b*, doorframe with door in position; *c*, cross section showing door and frame.

Doors for this frame are made of two thicknesses of tongued-and-grooved flooring with acid-proof building paper between the inside flooring running vertically and the outside horizontally. The doors are held in position by means of iron straps, one on each side, which project over a slat nailed to the doorpost. When the silage is being

used, instead of the doors being removed from the frames, they are slid up out of the way and held by a pin in the doorpost. The topmost door will have to be taken out, and this will make room for the other doors to be raised, one at a time, enough to give an opening.

As shown in figure 29, the doors are so made as to overlap

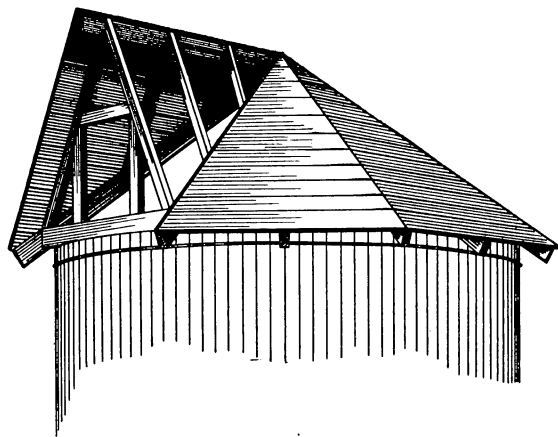


FIG. 30.—Roof with door in gable.

where they meet and thus make a tight joint. Patented doors with suitable frames can also be purchased.

ROOF, LADDER, AND CHUTE.

Figure 30 shows the framing and boarding for a good type of roof, with the door for filling the silo in a gable.

Figure 31 shows the same roof as figure 30, but with a trapdoor for filling, in place of the door in the gable.

A ladder should be attached to the silo at one side of the doors, and a chute, through which to remove the silage, should be built so as to inclose the ladder

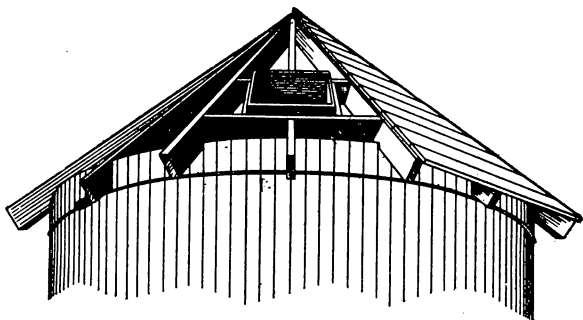


FIG. 31.—Roof with trapdoor for filling silo.

and the doors, as shown in figure 32. This should be large enough to permit a man to climb the ladder conveniently. In case the continuous door is adopted, the ladder may be dispensed with, as the hoops will serve for steps. (See fig. 29.)

PAINTING.

Before the silo is filled, it should be painted on the inside with raw coal tar thinned with gasoline. Every two or three years a fresh coat of this paint should be put on. When the timber in the silo is

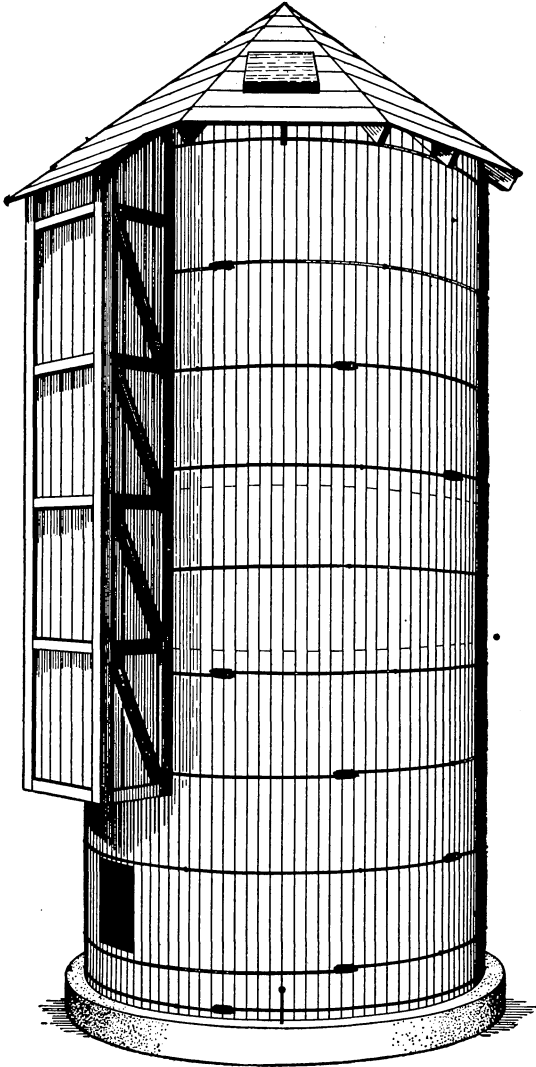


FIG. 32.—Complete silo with chute.

thoroughly dry, the outside of it should be painted to harmonize with the surrounding buildings.

THE MODIFIED WISCONSIN SILO.**FOUNDATION.**

The foundation for the modified Wisconsin silo is constructed the same as for a stave silo. Instead of eyebolts, use anchor bolts 16

inches long. These should be embedded in the foundation wall 6 feet apart and 3 inches from the inside edge, extending 5 inches above the top of the wall. (See fig. 37.)

SILLS AND PLATES.

The sills and plates are formed of two thicknesses of 2 by 4 inch pieces, 2 feet long, with the ends beveled to form a circle. The proper bevel may be determined in the following manner: From the center stake used in laying out the foundation wall draw a circle on top of the foundation wall 1 inch from the inside edge. At any point on this line lay a 2 by 4 inch piece, 2 feet long, with both ends at equal distances from the center; then use a slat with one edge on the center point of the stake and let the same edge on the other end of the slat

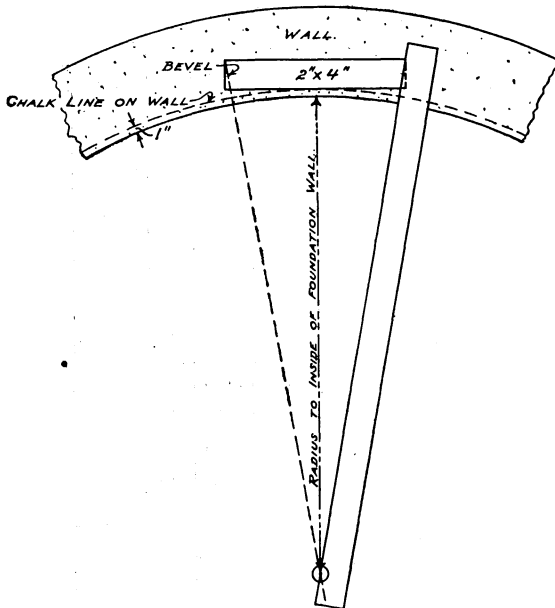


FIG. 33.—Method of obtaining bevel ends for sill and plate.

strike the outer corner of the 2 by 4 piece. A line drawn along the slat across the 2 by 4 piece will give the proper angle, or the bevel. The same process will give the bevel for the other end of the 2 by 4 piece. (See fig. 33.)

Use this piece as a pattern in cutting pieces enough to form the double circle for both sill and plate. The number needed will depend on the diameter of the intended silo. After cutting several pieces, lay them along the wall and note how they fit and make any necessary changes. When all of the pieces are cut lay them out on the wall along the line 1 inch from the inside edge of the wall, boring the necessary holes for the anchor bolts. On this layer place the second course, breaking the joints, then nail the two rings together and tighten up the nuts on the anchor bolts.

SCAFFOLDING.

As it will be necessary to have a scaffold inside the silo to put on the sheathing, it is preferable to put it up before the studs are in position. It can easily be made by standing up a pole in the center of the silo, with about six others around it, placed about 18 inches inside the foundation wall. Then brace these poles together, and wherever a stage is desired, nail pieces from the center pole to each of the outer poles, on which boards may be laid.

STUDDING.

The size of the studding used in the modified Wisconsin silo is 2 by 4 inches, and if not long enough to reach the desired height, they can be spliced with 1 by 4 inch pieces, 4 feet long, nailed on each side over the joint. (See fig. 34.) Whenever it is necessary to splice the studs the pieces should be of two different lengths, such as 12 feet and 16 feet for a 28-foot silo, and in setting up the studding the long and short pieces should alternate, so that all the splices will not come at the same height from the foundation.

It is preferable to do this splicing before the studs are placed in position. When all are spliced and cut to equal length they should be placed 1 foot apart from center to center, with the edge 1 inch from the inner edge of the foundation wall, or in line with the circle previously marked out in laying the sill, and then toenailed to the sill. Great care should be exercised to have the studs plumb on all sides and well braced to the inside scaffold so that the top of the silo will form a perfect circle. The plate can be nailed on as the studs are set. These should be laid in the same way as the sill, being careful to nail them firmly to the top of the studs.

At least two hoops formed from the thin sheathing should be nailed around the outside of the studding to keep them from bulging while the sheathing is being nailed on. These hoops can be removed after the sheathing has been placed on the inside.

STUDDING FOR DOORS.

It is preferable to set the door studs before the others are placed, so as to avoid trouble in getting the door in just the right place. The doorposts should be 4 by 4 inches and long enough for the height of the silo. If not, they may be spliced by halving and bolting. (See fig. 35.) Set them up to the line 1 inch from the inside edge of the

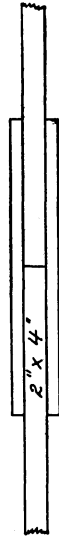


FIG. 34.—Method for splicing studding.

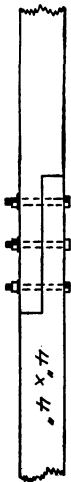


FIG. 35.—Method for splicing doorposts.

foundation wall, leaving a 24-inch space between. Toenail securely to the sill. The openings for the doors are made by nailing in

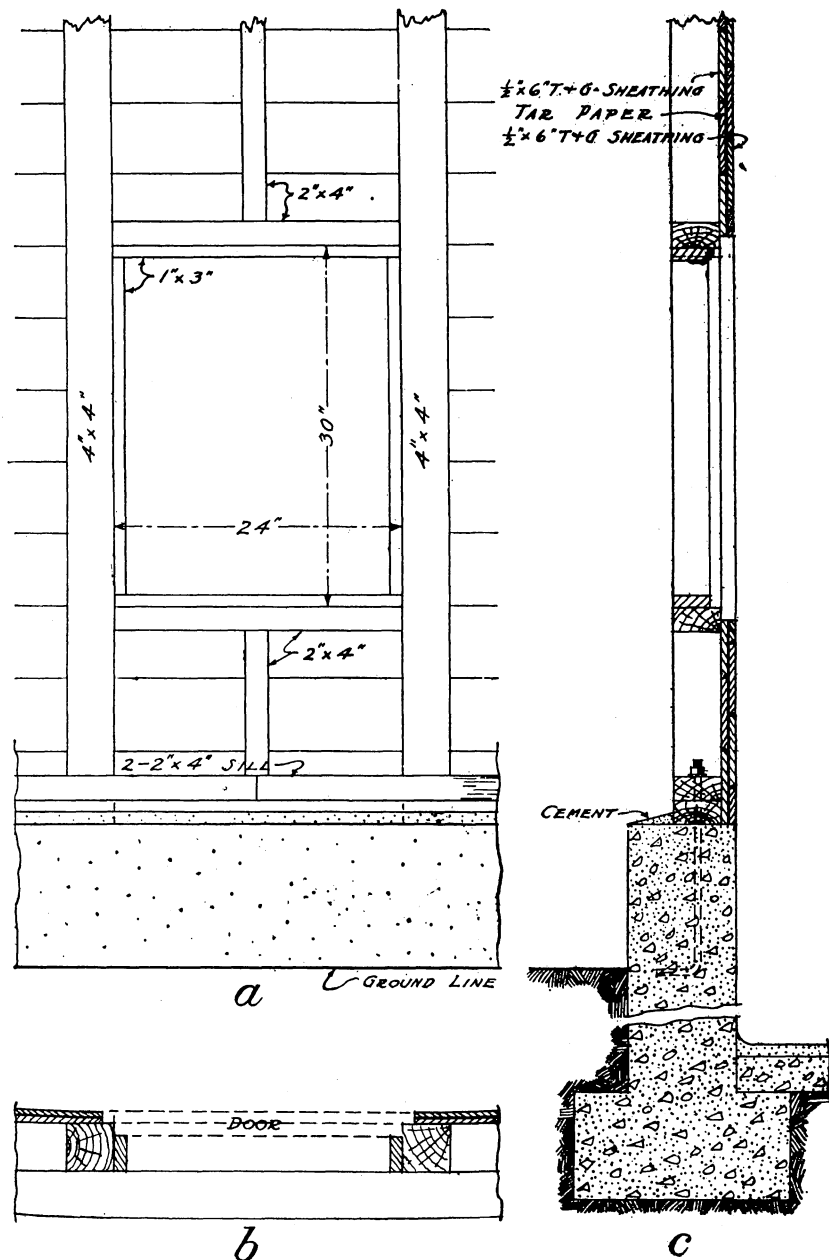


FIG. 36.—Details of construction of modified Wisconsin silo; a and b, detail of door opening; c, sectional view of foundation and wall.

headers and sills at the places where the doors are desired, leaving the spaces open when the inside sheathing is put on. For the size of the openings see figure 36a.

SHEATHING.

The sheathing will consist of $\frac{1}{2}$ by 6 inch material. Start at the bottom and work upward. To prevent uneven bending, the joints of the sheathing should come on different studs. At the door openings the sheathing should be cut back 1 inch from inside edge of door-posts to form a rabbet into which the doors should fit. (See fig. 36*b*.)

Two courses of the sheathing are put on the inside with a course of acid-proof building paper between. (See fig. 36*c*, which is a sectional view of the foundation and wall through the door opening.) In placing the sheathing see that all seams and joints are broken, that is, so that the cracks and joints in the first course will not come opposite to those of the second. It will be more convenient if these two courses are carried up to the top simultaneously.

DOORS.

The doors are made of two thicknesses of 1 by 6 inch tongued-and-grooved flooring, with building paper between, the inside course to fit neatly in the opening. The inside course should be vertical and the outside course horizontal. (See fig. 37.) A 1 by 3 inch strip is then nailed around the door openings 1 inch from the inside to form the outside door jambs.

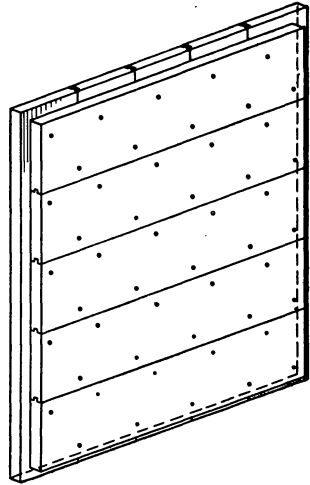


FIG. 37.—Door for modified Wisconsin silo (outside view).

ROOF, FLOOR, LADDER, AND CHUTE.

These are constructed just the same as for a stave silo.

BILLS OF MATERIALS.

One of the main questions which will confront the farmer who undertakes to build his own silo is, "What materials shall I need and how much of each kind?" Owing to the variation in size of silos, it is impracticable to give such information in detail here. If any farmer who desires such information will address a request to the Dairy Division, Bureau of Animal Industry, United States Department of Agriculture, stating the size and kind of silo he intends to build, a complete list of the materials needed will be forwarded to him free of cost.

